1/4 Bind arrears new

TM 5-240

U.S. WAR DEPARTMENT

TECHNICAL MANUAL

AERIAL PHOTOTOPOGRAPHY

November 21, 1941

133

TECHNICAL MANUAL } WAR DEPARTMENT,
No. 5–240 } WASHINGTON, November 21, 1941.

AERIAL PHOTOTOPOGRAPHY

Prepared under direction of the
Chief of Engineers

★★

410636°—41——1

CHAPTER 1

GENERAL

1. Purpose.—The purposes of this manual are to describe in detail proven methods of producing topographic maps by the use of aerial photographs and stereoscopic plotting instruments, as developed and practiced to date by engineer topographic units, and to provide a guide for the training and operation of Army topographic units in general.

2. Scope.—Practical step by step procedure of accepted methods will be described in sufficient detail so that a person can learn to produce an accurate topographic map by carefully following this manual and the operator's manuals and allied publications referred to herein. Only so much underlying theory will be discussed as is necessary for an understanding of the several processes. Alternate and optional phases of procedure will be described and evaluated. Effective individual use of the manual as a guide presupposes a fair knowledge of drafting, surveying, and aerial photography.

3. Mapping doctrines and theory.—*a.* The general mapping plan to include the responsibilities of the various mapping echelons is covered in FM 30-20.

b. This manual is designed primarily as a guide for the training of topographic battalions.

c. The mapping methods used by topographic battalions include those photogrammetric processes involving the radial line rectification of aerial photographs and stereoscopic plotting instruments for the measurement of differences in elevation. Computations based on direct measurements made on photographic prints or negatives are not used. The photogrammetric theories involved, including the derivation of proofs, are not included herein but are available in several books written on the subject. While they are based on the rather exact science of photogrammetry, the map making methods described herein ignore those theoretical errors which do not seriously impair the accuracy of the resulting map.

d. Depending on the situation which confronts a topographic battalion, certain liberties may have to be taken to produce a map suitable for military purposes in the shortest possible time. Difficulties in the procurement of field control in military operations may force the extension of control by photogrammetric processes to cover abnormal distances, but even under these conditions a usable map may be produced, although it may not conform to standard peacetime specifications. Since the timely production of a usable map will often be more desirable than the deliberate production of a more accurate map, training must be directed toward the development of an organization capable of rapid production with every means at its disposal. The topographic battalion must be trained to use all of its equipment on a single job, as occasions may arise when all topographic plotting instruments must be used to meet the time objective. Flexibility in the map making procedure should be stressed. There should be no hesitancy in using any combination of the map making methods described which may best answer a particular problem.

e. In the map making methods to be described, those errors which have no material effect on the accuracy of the map are ignored. Such errors occur largely as a result of tip and tilt in the camera at the time of exposure. Although normally it may be desirable to conform to peacetime specifications, when the area to be mapped is large and field control must be limited, the military requirements alone may be considered. For example, it may be considered satisfactory if any particular portion of the map having an area which can be covered by field artillery conforms to specification accuracy. In other words, these artillery zones might be considered as having their own datum and their own geographic reference point.

f. In laying out the work of the survey companies for emergency projects, priorities should be established so that the most essential field control is procured first and submitted by increments as it becomes available. Photomapping may be started with limited field control and improved when and if more control becomes available.

g. The topographic battalion is a balanced unit. That is, the subunits which handle the various phases of the complete mapping process are so organized and equipped that, if everything goes well, there will be smooth, uninterrupted progress from the inception of the project to the finished map sheets. This requires careful advance planning and coordination, particularly as between the work of the photomapping and reproduction companies. There should be no delay in getting manuscripts into the hands of the reproduction company as they become available. Some drafting assistance may be furnished

the reproduction company by the photomapping company if a drafting bottleneck arises as a result of the completion of much manuscript at the same time.

h. In order to meet the requirements prescribed in FM 30–20, the topographic battalion must be kept constantly alert to its wartime mission and kept trained to fulfill it. This mission includes not only aerial photographic mapping of unmapped areas, but any other type of work which may well be expected of a topographic battalion, such as revision of existing maps, plane-table topography of limited areas to scales not feasible for aerial photomapping, the compilation of existing maps to suitable scale or sheet size, etc. Notes on training for photomapping (especially for multiplex) appear in appendix I. Detailed directions to accomplish the special tasks just mentioned are found in TM 5–230 and in TM 5–235.

i. An aerial photograph may be considered as a perspective projection of a portion of the earth's surface. The photograph itself is a contact print from an aerial negative or film. The exposed negative of an aerial camera may be considered as the result obtained by intersecting with this negative a bundle of light rays, infinite in number, emanating from the area photographed and passing through a perspective center represented by the camera lens. When a plane intersects the bundle of rays between the perspective center and the objects photographed, the resulting photograph is called a positive, and when this photograph is on a transparent medium, such as glass, the result may be called a diapositive.

j. The plumb point on an aerial photograph is that point which represents the foot of a perpendicular from the center of the camera lens to the ground photographed.

k. By means of geometrical analysis it may be proved that on a truly vertical aerial photograph the true position of all points or objects photographed will be along rays drawn from the plumb point, regardless of the elevation of the object.

l. All aerial photographs are characterized by natural photographic displacements due to relief. From figure 1 it can readily be seen that a hilltop of elevation h will be represented on the photograph at the point A^1. The point A^2, being on the same light ray, will likewise be represented on the photograph at the same point A^1. If the point A had been at sea level as at A^3, it would have appeared in the photograph at the point A^4. The displacement due to relief is the distance $A^1\ A^4$ on the photograph or $A^2\ A^3$ on the ground. The photographic displacement $A^1\ A^4$ is the displacement which must be corrected for in aerial photographic mapping in order to represent objects in their true positions. In the stereocomparagraph

method, this is done by means of the radial line plot described in this manual. If the altitude of the plane H, the elevation of the object, and the focal length of the camera f are known, the amount of the displacement may readily be computed for any point on a photograph whose distance from the principal point may be measured. Theoretically these displacements are along rays drawn from the plumb point on the photograph, but the determination of the position of the plumb point is rarely possible and is for all practical purposes, with tip and the tilt not in excess of 3°, and with relief a small percentage of the flight altitude, close enough to the principal point so that no appreciable error is introduced in using the principal point as the origin of the rays.

m. The sum of the displacements on two overlapping aerial photographs is the parallax which makes possible the stereoscopic or mathematical determination of differences in elevation of picture points.

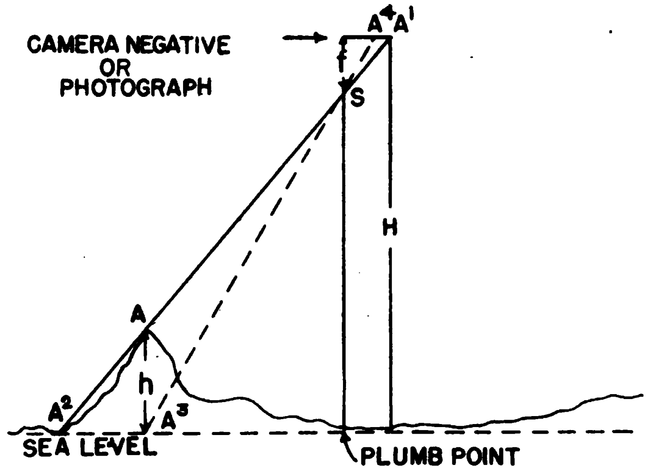


FIGURE 1.—Displacement due to relief.

n. The effect of tip and tilt in the camera on the displacements of objects depicted in an aerial photograph may be computed for any given amount of tip and tilt by geometrical analysis. For a combined tip and tilt of 3° with a K-3B, 8¼-inch focal length camera the photographic displacement due to this tip and tilt will be a maximum of approximately 0.06 inch. The displacements caused by tip and tilt may be considered as errors and are normally small enough to be ignored in radial line plotting, but are provided for in stereoscopic plotting of topography.

4. Characteristics of aerial photographs.—*a.* A thorough knowledge of the characteristics of aerial photographs is essential to an understanding of the advantages as well as the limitations of

aerial photographs in map making. For a detailed discussion of this subject see TM 5-230.

b. The theory and practice involving the determination of differences of elevation of objects on overlapping photographs by measurement of differential parallax is covered in TM 5-230.

5. Definitions.

Absolute orientation.—The orientation of two or more multiplex projectors to reproduce a perfect spatial model, fitting known control.

B print.—The print made from the central or vertical chamber of T-3A or tandem T-3A cameras.

Bridging.—Extending control between bands of existing control by photomapping methods.

Cantilever extension.—The extension of control from a base line into an area where no field control is available.

Collimating mark.—A mark normally appearing as a notch, line, or both on aerial photographic negatives and prints therefrom and representing predetermined positions permanently marked in the camera and transferred to every negative as pictures are taken.

Compilation.—The process of extracting map detail from aerial photographs or other sources to fit a control network in the preparation of a new map.

Composite.—The assembled photograph made from simultaneous exposures of one or two multiple lens cameras.

Contact print.—The print made from a negative in direct contact with sensitized paper.

Control.—A system or network of points of fixed geodetic positions, with latitude, longitude, and elevation determined with surveying instruments.

Crab.—Angle between the edge of a photograph and the flight line.

Diapositives.—Positive prints on glass; for use in projecting a view with a multiplex projector.

Flight line.—A course laid out on a map to be followed by an airplane; also the actual course followed by the airplane in flight.

Horizontal control.—A system of points of known location in a horizontal plane. Points of horizontal control are those whose geographic coordinates are known.

Hypsography.—The part of a map which represents relief, such as contours and contour numbers.

Manuscript.—The original completed work as accomplished by multiplex topographers or compilers.

Multiplex projector.—An optical projection instrument which can be oriented to assume the same position with respect to the projected image as the aerial camera had with respect to the ground at the instant the exposure was made. Multiplex projectors are stereoscopic plotting instruments.

Overlap.—Portion of a photograph common to another photograph along a line of flight.

Picture points.—Field control points, the exact locations of which can be spotted on the aerial photographs used in photomapping.

Planimetry.—Those features of a topographic map which represent the works of man, hydrography, and woods, i. e., everything except the representation of relief.

Plate pair.—The area common to two aerial photographs overlapping along the line of flight.

Principal point.—The foot of the perpendicular from the inner node of the photographic lens to the focal plane of the camera, usually the physical center of the aerial photograph.

Projection.—The representation of a portion of the earth's surface on a plane surface.

Radial line plot.—A method of plotting in which the geographic positions of points appearing on aerial photographs are determined by means of rays drawn to the points and radiating from the photo centers.

Reduction printer.—Special printer to make diapositives from original aerial negatives for multiplex use.

Relative orientation.—The orientation of one multiplex projector with reference to another to reproduce the relationship of the taking cameras.

Shadowgraph.—That portion of the margin of an aerial photograph appearing as a black border. It normally contains the collimating notches.

Sidelap.—The area in common to two aerial photographs on adjacent lines of flight.

Spatial model.—Relief model seen by observing a plate pair through stereoscopic instruments.

Starting control.—The field control available to permit an absolute orientation of the first multiplex projections of photographs along a given line of flight for which control is to be extended.

Stereoscopic model.—An optical three dimensional reconstitution, usually in miniature, of an object or view by means of superimposed projected images of a pair of photographs. Specifically, in photomapping, such an optical reconstruction of a portion of the earth's surface.

Stereoscopic pair.—A pair of photographs having some portions in common, taken from different camera stations.

Tip.—Motion around a horizontal axis perpendicular to the line of flight.

Tilt.—Motion around a horizontal axis parallel to the line of flight.

Topographic plot.—A representation by means of contour lines of the ground relief in a stereoscopic model.

Topography.—The configuration of the surface of the ground including its relief, the position of its streams, roads, etc.

Vertical control.—A system of points whose elevations referred to sea level have been determined instrumentally.

Wing print.—Transformed print from negative of an oblique chamber of a T-3A or tandem T-3A camera.

Working scale.—Plotting scale or the scale of the manuscript.

CHAPTER 2

MAP MAKING METHODS

6. General.—There are many map making methods involving aerial photographs and various types of stereoscopic plotting instruments which are used throughout the world. From the various types of stereoscopic plotting instruments available, the United States Army has selected the multiplex projector and stereocomparagraph equipment as the types which best meet the needs of topographic battalions. Therefore, this equipment is now issued as the basic stereophotogrammetric equipment, and all map making methods developed and practiced by topographic battalions utilize it as such. The stereocomparagraph is supplied to topographic battalions to fill the need for a simple stereoscopic plotting instrument suitable for plotting topography from stereoscopic pairs for which vertical control (a minimum of three elevations well distributed in the common area of the pair) has been provided. It may be used in conjunction with multiplex equipment to provide an additional map making method to augment the exclusively multiplex method, when multiplex equipment or trained personnel therefor is limited. With multiplex equipment, measurements are made and plotting is done from an orthographic or correct spatial model, and the resulting plot is ready for direct incorporation in the map. This is also true with certain other types of plotting instruments such as the aerocartograph, not in use by topographic battalions. With stereocomparagraph equipment, plotting is done from a perspective spatial model retaining the displacements due to relief and tilt, and the result must be rectified to an orthographic projection by the separate execution of a radial line plot to remove these displacements. Any type of equipment similar to the stereocomparagraph which permits of stereoscopic plotting of topography direct from photographs held in a horizontal plane may be used in conjunction with a radial line plot. Based on the above distinction, the two methods in use may be broadly classified as the orthographic method and the perspective method. In the topographic battalions, these classifications will be made to conform to the type of equipment now being supplied and the two methods hereafter identified as the multiplex method and the stereocompara-

graph method. The use of either method can be made to produce a topographic map of standard specifications suitable for practically all military needs. The selection of the method to be used will be dependent on the state of training of stereoscopic plotting machine operators or phototopographers and compilers, and the availability of equipment. Both methods will be described in detail.

7. **Multiplex method.**—In the multiplex method of map making, all plotting of the map, including planimetry and hypsography, is accomplished by multiplex operators, each working on his assigned section. The sections are later assembled to form a manuscript copy of the map. With control available no more than 15 miles apart, no radial line plot need be made, but when a map must be extended great distances beyond known control, it may be found advantageous to make a radial line plot for the purpose of establishing a horizontal control network on which multiplex work may be based. In this case, the horizontal control obtained by the radial line plot may at least speed the completion of the map if not improve its accuracy. Unless a radial line plot is considered desirable, no composite photographs need be mounted when multiple lens cameras are used, no topographic points other than field control points need be pricked, and only the projection at the scale of multiplex operation need be prepared. Considering a specific mapping project in which the photography was at 20,000 feet flight altitude with a 6-inch focal length camera, the manuscript of a multiplex map would be at a scale of 1:16,000, while the manuscript of a stereocomparagraph map would be at a scale of 1:40,000.

8. **Stereocomparagraph method.**—In the stereocomparagraph method of making a map, the multiplex projectors are used only for the purpose of extending or multiplying the vertical control available so that a minimum of three known elevations are available in each stereoscopic pair to be contoured with the stereocomparagraph. In this method a radial line plot is made for the purpose of determining the true position of a network of picture points about an inch apart. This horizontal control network may be used to assist the multiplex operators in extending or multiplying vertical control, and is used as a base on which the map is compiled. Planimetric detail is compiled directly from the original photographs at approximately the scale of the photographs, and topography is compiled from the separate individual topographic plots produced by the stereocomparagraph operators. In this method, composites must be mounted when multiple lens cameras are used, and points must be pricked on photographs to a density of about one per square inch.

CHAPTER 3

PROCEDURE BY MULTIPLEX METHOD

SECTION I

PHOTOGRAPHY

9. Selection of camera.—The cameras to be used must be precise aerial photomapping cameras of a type for which reduction printers are available. These include the K-3B 9 by 9 inch or 7 by 9 inch, 8¼-inch focal length camera (fig. 2), the T-3A or tandem T-3A 6-inch focal length camera (fig. 3) for units equipped with the normal multiplex equipment, and the T-5, 6-inch focal length wide angle camera and 6-inch wide angle lens cone (fig. 4) for units equipped with the wide angle multiplex equipment. The reduction printer must be able to print diapositives suitable for use in the multiplex projectors available. Photography by cameras for which this cannot be done is useless for multiplex mapping except insofar as interpretation of detail or other intelligence studies may be concerned. The camera should be equipped with a vacuum back film holder to hold the film perfectly flat without the optical interference of a glass plate; it should have a speed capable of practically stopping motion at a normal flying speed of 150 miles per hour; it should be equipped with an intervalometer to permit accurate timing of exposures; it should be designed to operate in extreme cold at high altitudes; it should be mounted in such a way as to permit crabbing and leveling as pictures are taken; and it should be equipped with a data recording unit to record the time of day, exposure number, altimeter reading, and temperature. The data recording unit is not vitally necessary, but will be of considerable aid in cantilever control extension

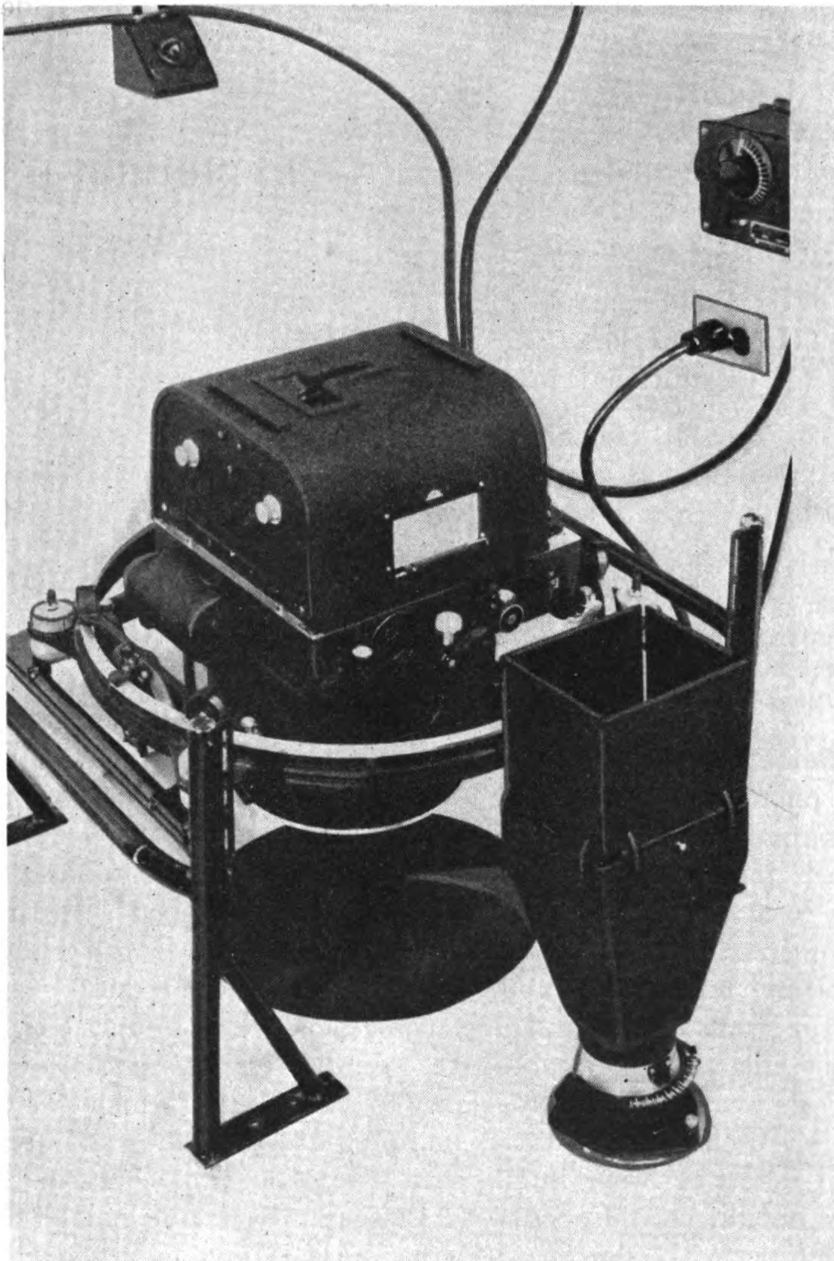
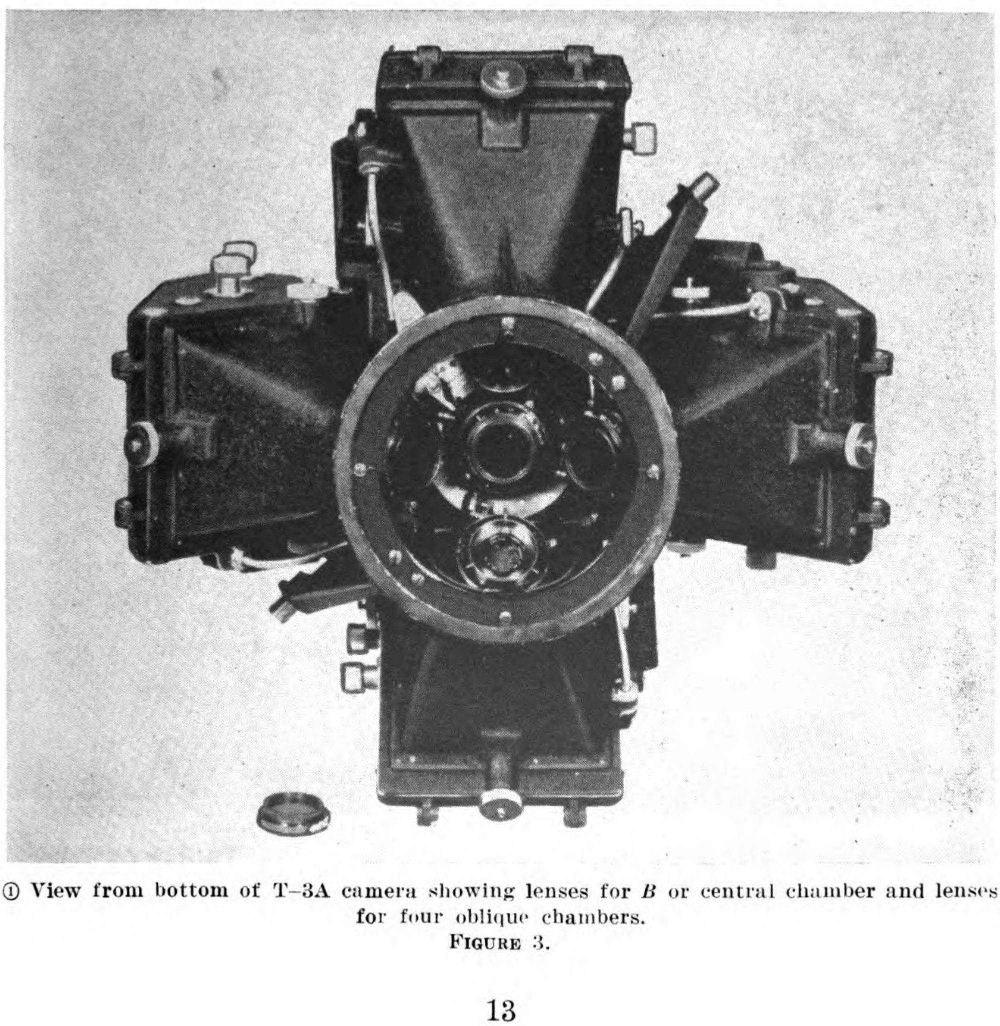


FIGURE 2.—K-3B camera mounted with view finder.

work. The choice of the specific camera to be used is dependent on the availability of photographic equipment, the size and nature of the job to be done, the tactical situation, the amount of control available, and the accuracy desired in the map. For large areas to be mapped from photographs taken at high altitude, and where the tactical situation demands the minimum of flying for photography, a multiple lens camera or wide angle camera should be used. When

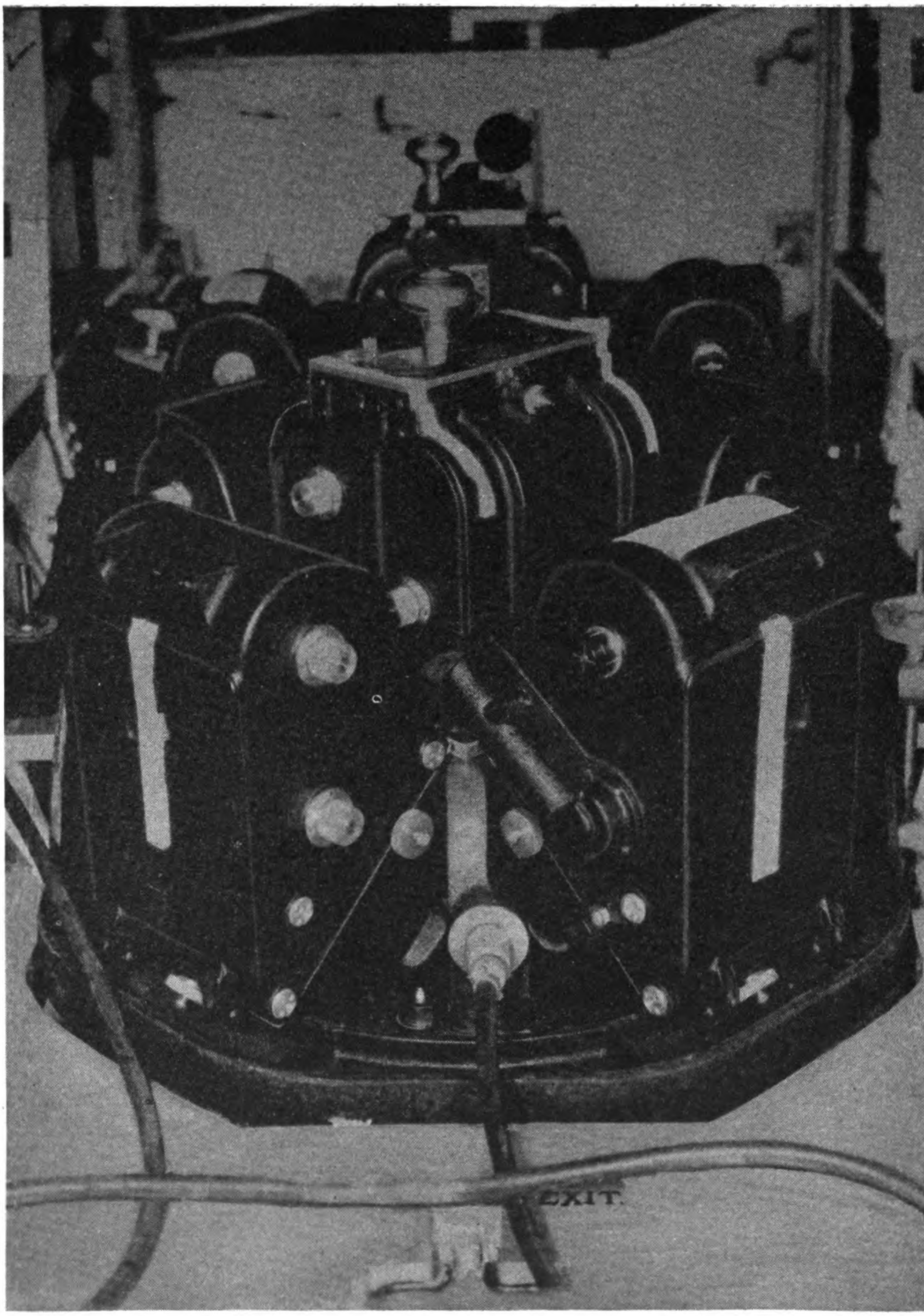
the area is small, is to be flown at low altitude, and the map is desired with greatest accuracy, a single lens camera may be used or the area may be covered with the vertical chamber of the multiple lens camera.

10. Preparation of flight map.—Having selected the type of camera to be used, the flight map may be prepared. The flight map should provide complete coverage of the area to be mapped with liberal allowances for departure from prescribed flight lines. Two major considerations are to be borne in mind: the desirability of having flight lines run north and south and the desirability of having flight lines perpendicular to bands of control. In some cases these considerations may be opposed. Having determined the location of existing control and the most likely locations for bands of projected field control, flight lines should be drawn perpendicular to these control bands. Outside flight lines should be drawn so that the picture centers fall outside of the project, and each flight line should be extended so that at least one picture falls entirely outside of the project. Intermediate flight lines should provide 30 percent side lap for single lens pictures



① View from bottom of T-3A camera showing lenses for *B* or central chamber and lenses for four oblique chambers.

FIGURE 3.



② Two T-3A 6-inch focal length cameras mounted in tandem.

FIGURE 3—Continued.

and 60 percent side lap for multiple lens composites. It is desirable to locate flight lines so as to give good ground features by which the pilot may control his flights. With a well-trained photographic crew it may be desirable to specify the minimum side lap desired and omit intermediate flight lines. A cross flight at one or both ends of the project is often desirable for the purpose of multiplying the vertical control of

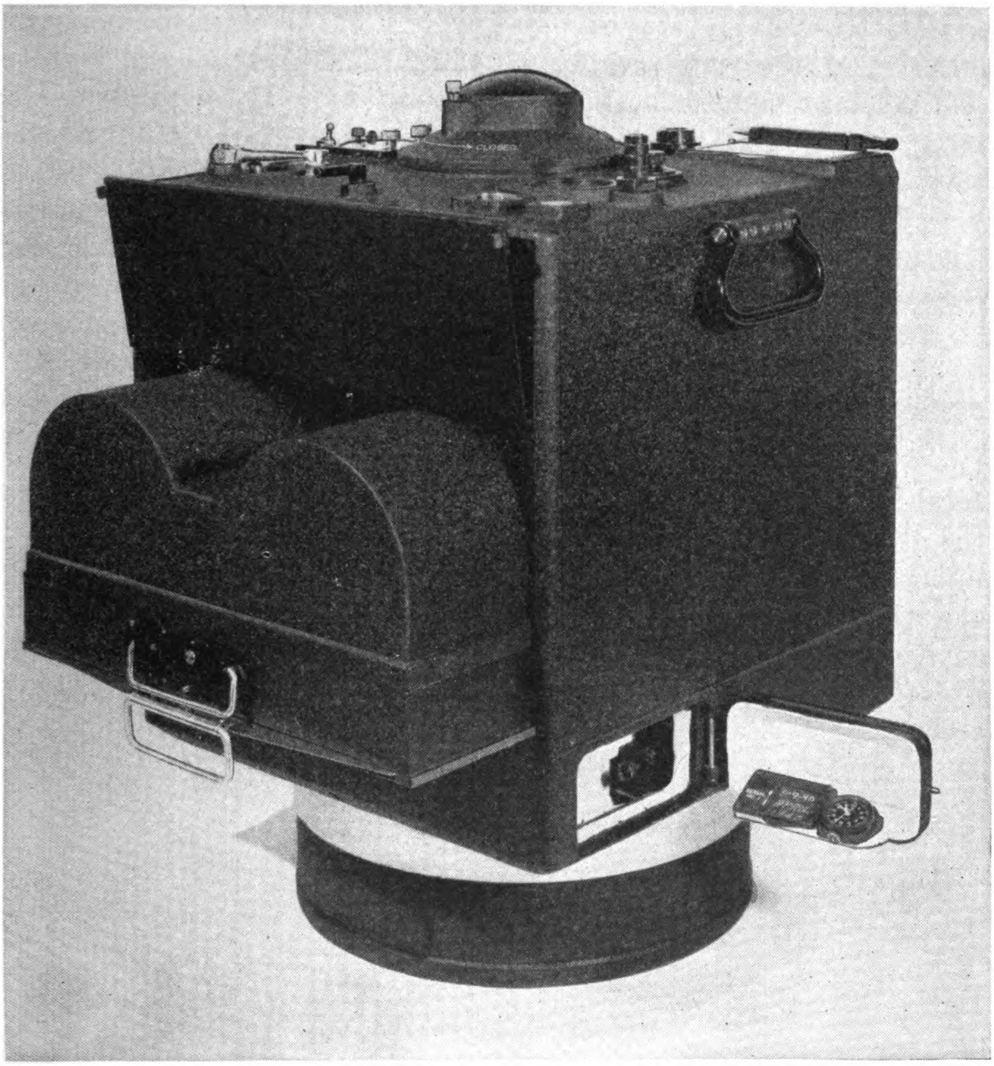


FIGURE 4.—T–5 6-inch wide angle camera.

a control band so that a well-controlled start may be made with the multiplex on any selected flight lines. This applies where starting control will be limited. Diagonal flights may be desirable where it is desired to shorten the vertical control extensions and provide an independent means of checking the accuracy of vertical control extensions along flight lines. To determine the spacing of the flight lines it is

necessary to know the scale of the map being used for the flight diagram, the flight altitude, the focal length of the camera to be used and the size of the resulting contact print. By inspection of figure 5, it may be seen that if the ground is assumed to be a plane surface, any distance on the photograph, such as $a' b'$, bears a relation to the corresponding distance on the ground, AB, equal to F/H, where F is the

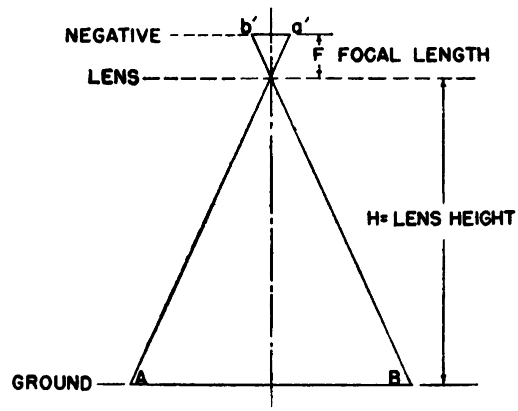


FIGURE 5.—Diagram showing relation of scale, focal length, and lens height.

focal length of the camera and H is the height of the camera lens above the ground (both F and H being expressed in the same unit of measurement). Since the altimeter of the airplane usually expresses the elevation above sea level in place of H, the expression H_a–E must be substituted, H_a being the altimeter elevation above sea level and E the average elevation of the terrain shown in the photograph. We may accordingly write—

$$\text{R.F.} = \frac{F \text{ in feet}}{H_a \text{ in feet} - E \text{ in feet}}.$$

$$F = 8\tfrac{1}{4} \text{ or } 8.25/12 \text{ feet.}$$

$$H_a = 21{,}000 \text{ feet.}$$

$$E = 1{,}000 \text{ feet.}$$

$$\text{R.F.} = \frac{\frac{8.25}{12}}{21{,}000 - 1{,}000} = \frac{1}{29{,}090}.$$

With a picture 9 inches wide perpendicular to the direction of flight, there is a coverage of 9 by 29,090 inches or 4.13 miles. To provide a 30 percent side lap, the flight lines must be closed up by 30 percent of 4.13 or 1.24 miles. This requires the flight lines to be spaced 4.13−1.24 or 2.89 miles apart. Under most conditions it is more

desirable to exceed 30 percent side lap than to fall below and thereby perhaps fail to obtain complete coverage. In drawing the flight lines when all intermediate flight lines are to be established before submission of the flight map to the Air Force, it may occasionally be necessary to consider carefully the variations in elevation of the terrain to be photographed in order to space the lines properly. An abrupt change of ground elevation of considerable magnitude may so change the scale of the resulting photography as to cause a flight diagram laid out for sea level photography to have insufficient tolerance in side lap. For example, an abrupt escarpment of 2,000 feet elevation in one line of flight will reduce the width of ground covered by the pictures by 10 percent, or if several lines of flight pass over terrain of this elevation, spacing of flight lines for the K-3B 9 by 9 inch photography at 20,000 feet altitude must be reduced from approximately 2.9 miles to approximately 2.5 miles. An example of a flight map is shown in figure 6. (See par. 69, TM 5-230.)

11. Specifications for photography.—*a.* The amount of detail in specifications for photography may be dependent to some extent on the training of the Air Force photographic personnel. It is

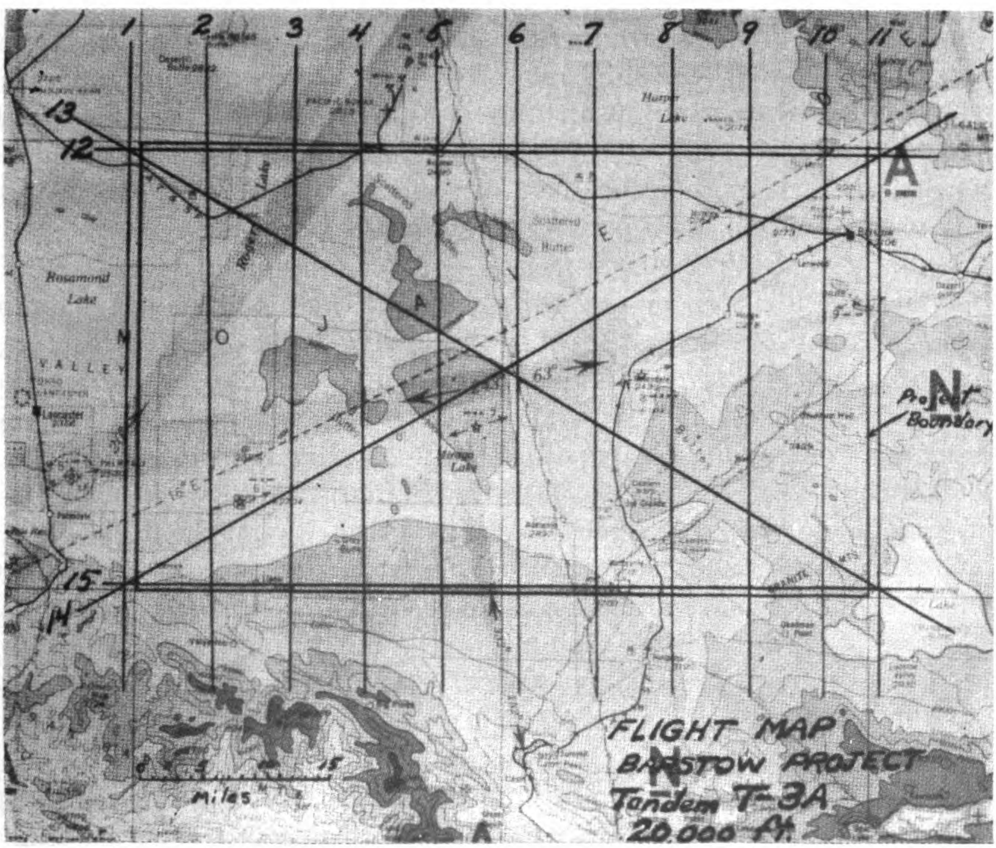


FIGURE 6.—Flight map for tandem T-3A camera.

probably wise to err on the side of too much detail and include all desirable objectives. The specifications should include the flight altitude at which the pictures are to be taken and a caution that this altitude should be maintained as closely as possible and with temperature correction applied in accordance with the Air Force Technical Manuals; a specification as to the type of camera to be used; a specification providing for minimum crab, and tip and tilt not to exceed 3°; a specification that airplane speed and camera speed be coordinated to stop motion in the resulting photography as much as possible; a reference to the flight map submitted; a specification that topographic film be used; and a specification as to the overlap and side lap desired. In the event that photography is to be accomplished with the K-3B 8¼-inch camera taking 7 by 9 inch pictures, it is desirable to plan the flight diagram and specify that the photography be accomplished so that the 9-inch dimension of the resulting pictures will lie along the flight lines and not perpendicular thereto, as normally taken for intelligence purposes. Turning the camera and providing guide lines on the view finder for the control of overlap to accomplish this result with the 7 by 9 inch camera is not a difficult operation. Before specifying the details as to the photography required to accomplish a particular task, there are several things to consider which may affect the flight altitude used, the type of camera, or both. For military purposes the determination of flight altitude is based largely on tactical considerations, such as relatively safe flying height, minimum flying requirements, etc. It is therefore best to train in the use of high altitude photography, and such photography should be specified to be taken at a flight altitude of 20,000 feet or more. Occasions may arise where the contour intervals or specified scales for the manuscript are dominant requisites, and photography will have to be made to fit these requirements. The permissible contour interval may be determined from experience, which indicates that the accuracy of multiplex contouring from photography with the T-3A cameras is such that the contour interval should be $1/500$ of the flight height (or where the average height of the terrain involved is great, $1/500$ of the flight height above the mean ground elevation) to insure contour accuracy to within one half the contour interval. In an accurately controlled model, spot elevations of well-defined points may be determined to within $1/3000$ of the flight height. Thus, with T-3A camera photography from 20,000 feet altitude above the mean ground elevation, spot elevations can be determined accurately to within 7 feet, but the contour interval should be 40 feet. The contour interval actually selected will vary with the specific control and terrain conditions. For instructions as to how to select the camera and flight height to secure a specific contour

interval, see the Multiplex Operators Manual, published by the engineer detachment, Wright Field, Dayton, Ohio.

b. In determining the manuscript scale which will result from photography at certain flight altitudes with various cameras and when the normal multiplex equipment is to be used, certain characteristics of the multiplex equipment must be known. Normal multiplex projectors may be used in a range from 280 mm to 450 mm above the tracing table, by means of which measurements are made. The optimum plotting distance or the distance between the projectors and the tracing table which provides the sharpest image to the operator is 360 mm. A plotting scale should be used which utilizes this optimum plotting distance, and it may be deduced as follows:

(1) The plotting scale is the ratio of the projection distance to the mean flight height.

Example: For pictures taken at 20,000 feet, assuming the average ground level to be sea level, regardless of the camera used, the plotting scale is 360 mm/20,000 ft.=1/16,940. An even scale is normally used, and as considerable range is available, 1:16,000 may be used in this case.

(2) If the average elevation of the ground had been 1,000 feet, the mean flight height would have been 19,000 feet and this figure would be used in place of 20,000 as above. The above relationship permits the selection of the flight altitude to produce a certain manuscript scale or vice versa.

12. Requisitions for prints and negatives.—The request for photography, including specifications and flight map, is submitted through channels to the Air Force unit which is to accomplish the photography. At the same time it is desirable to request a sufficient number of quick prints so that a determination may be made as to compliance with specifications. For single lens photography one set of quick prints should suffice to permit determination as to whether or not reflights will be necessary. For multiple lens photography a complete set of quick vertical prints or prints from the vertical chamber which was square to the line of flight, and one quick print of each of the two wing pictures perpendicular to the line of flight at each end of every flight, should be sufficient. When a good flight map is available, such as will permit accurate plotting of the B prints, the wing prints may not be essential. After having checked the photography for adequacy by the quick prints, a request should be prepared for the additional prints of negatives desired. For single lens work, three prints of each picture on desired type of

paper and all negatives should be requested. For multiple lens photography when the tandem camera is used, prints on semimatte double weight paper, double weight glossy paper, or pigmented film base should be requested to provide complete composites with centers no more than 7 inches apart. Care should be taken to select composites from adjacent lines of flight so that they will be directly opposite. In addition there should be requested two prints each on semimatte paper of every B print squared to the line of flight, and of such continuous series of wing prints perpendicular to lines of flight as will provide complete stereoscopic coverage considering these wing prints as usable to a point not much farther out than the collimating marks. The same system should be used in determining the prints required from cross flights or diagonal flights. The negatives required will be those of the B chambers of the camera squared to the line of flight and those of the wing chambers, prints of which were requested above to provide complete stereoscopic coverage of the area to be mapped. (When submitting specifications for photography, the number and kind of prints to be required should be stated.)

Section II

FIELD CONTROL

13. General.—Field control is made up of those points whose positions and/or elevations have been determined instrumentally. In the topographic battalion, the field survey companies determine the coordinates and elevations of a number of points located in such a way as to permit extension or multiplication thereof by photogrammetric processes and recover field control established by other agencies. All possible use should be made of control established by other agencies. It should be recovered and reported even though it may not be possible to determine the exact position of the points on the photographs to be used in making the map. Every effort should be made to prick precisely such control on the photographs, but if the positions cannot be pricked most precisely, no attempt should be made to prick the points at all. The general areas each containing such a point may be circled and complete descriptions submitted. The precision required in pricking points is described in paragraph 16. Generally, the network of field control should be such as

to provide control bands approximately 15 miles apart, with a flight height of 20,000 feet and perpendicular to the lines of flight. This normal procedure will require the photomapping company to bridge 15-mile intervals with its multiplex equipment. Bridging greater distances and cantilever extensions of considerable length are possible, but such work should not be done when it is desired to conform to standard specifications for maps to be used by any agency in time of peace. To permit accurate bridging from one control band to another, it is necessary to have the area included in the overlap of two overlapping pictures at each end of the bridge rigidly controlled. These plate pairs are controlled by determining the correct positions and elevations of at least three and preferably five or six well placed points. For multiple lens photographs, the control of plate pairs for the vertical pictures only is required. Such additional control as may be readily procured incidental to securing the control of selected plate pairs should be reported as it will lend greater strength to the control network and facilitate control extension. For example, when it is determined that a traverse will be required to extend field control into the area covered by a plate pair selected as one to be controlled, additional points along the traverse though falling outside of the plate pair involved should be pricked and data thereon submitted. For a survey company not thoroughly familiar with the needs of the photomapping company, it will be necessary to provide a detail lay-out of the control points required. The methods to be used in procuring the positions and elevations of control points required are normal field survey methods of second order accuracy for triangulation, third order accuracy for traverses, and an order of accuracy for additional points not falling on traverses or triangulation such that the points will be within 10 feet of their true horizontal position for a publication scale of 1:20,000, and within 2½ feet of their true elevation when the map contour interval is to be 20 feet or more.

14. **Recovery.**—The corps area engineer, map making, road building, utility agencies, and other agencies in the area which do extensive survey work should be contacted with a view toward determining what control is already available. With these data accumulated, recovery parties are sent out to locate usable control, and if possible, prick the positions of the points on the photographs of the area. If the location of the recoverable control can be spotted on a photograph, a detail sketch should be prepared to a large scale showing the exact position of the control point with reference to the planimetric feature involved. Whether or not this recovered control falls

within the area of plate pairs to be controlled, it should be pricked where possible and always reported on the proper transmittal form. Recovered control, though not used as picture points, may be used as starting points for traverses or triangulation nets found necessary to supply the control needed by the photomapping company.

15. Control lay-out.—*a.* Bearing in mind the general requirements noted above, the lay-out for necessary control can be prepared most advantageously by a study of the terrain and road net for accessibility, using any available map and the photographs of the area. A plate pair near the edge of the project should be selected such as will provide a suitable number of readily identifiable points well spaced to provide the strongest possible triangles. It is important to bear in mind the requirements for a well-controlled plate pair in making this selection. Figure 7 indicates a plate pair and the most desirable

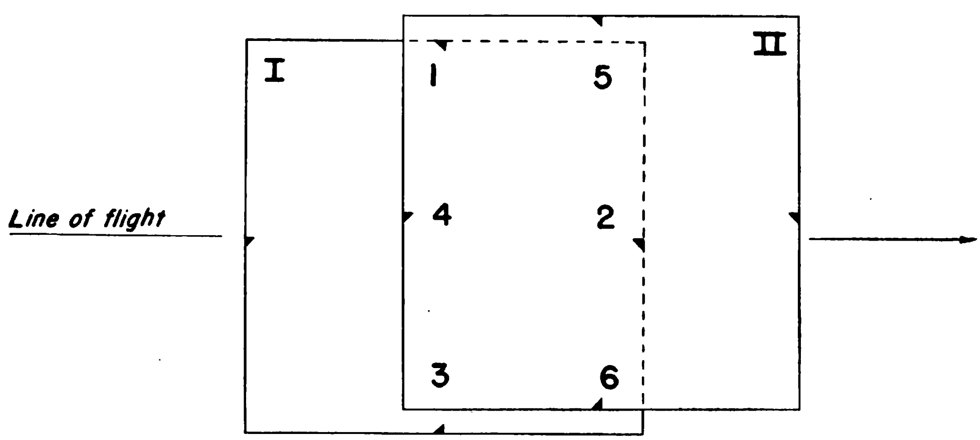


FIGURE 7.—Plate pair with field control marked in order of priority.

locations for field control therein in order of priority. Points 1, 2, and 3 or points 4, 5, and 6 must be secured to permit absolute orientation of the model with multiplex equipment. The farther apart these points are the stronger will be the orientation. If points 1, 2, and 3 are selected as the easiest to obtain, points 4, 5, and 6 should next be considered. It is highly desirable to locate the positions and elevations of four or five points at least in the plate pair formed as above by pictures I and II. The next plate pair to be controlled should be approximately 15 miles farther along the line of flight when the flight height is 20,000 feet. This pair may be from 10 to 18 miles away from another controlled pair depending upon what difficulty is encountered in finding a suitable plate pair with readily identifiable points and considering accessibility. Also to be borne in mind is the necessity for having at least 75 percent of the plate pair cover land area, unless the water in the

pair is completely surrounded by land. Water surface is not susceptible to stereoscopic observation and therefore it is to be considered as void space in measuring the strength of a resulting stereoscopic model. Having made the selection of plate pairs to be controlled throughout the area to be mapped, the picture points to be procured (identifiable points for which control is to be procured) should be selected in accordance with the diagram above. A circle of about one inch in diameter should be drawn on the photograph with a china marking crayon inclosing an area in which a control point is desired, leaving to the field survey party the selection of the exact point to be controlled. Recovered control which can be pricked should be considered both in the selection of the plate pair to be controlled and in the lay-out of control in the plate pair. Where it becomes necessary to start the establishment of field control before the photography has been accomplished, the flight lines must be used as guides. Attempts must be made to anticipate where the photography is likely to fit, and to arrange the control network so as to make certain that plate pairs will be controlled regardless of where they happen to fall. If, later, photography is misplaced with reference to the control established, it will then be necessary to add more control until at least the minimum requirements are met.

b. After having made the selection of the control net to be established and having circled the general localities of picture points as described above, a mosaic may be prepared or the positions of the points selected may be transferred to a suitable available map for ready reference by the field survey parties.

16. Selection, pricking, description, and submission of picture points.—*a.* When the control lay-out has been prepared in accordance with instructions outlined above, the field parties are in a position to procure the necessary data in the field with their surveying instruments when necessary or by recovery of existing control when possible. The photographs of the area should normally be available so that selected picture points may be pricked in the field as the various picture points are occupied. Whether the picture points be established by triangulation or by traverse, care should be exercised in selecting the precise location of the picture point station. The fundamental rule to remember is that the picture point must be readily and precisely identifiable on the photograph. For example, the top of a hill having no recognizable feature thereon may be occupied as a triangulation station, but it may not be pricked as a suitable picture point because it may not be possible to prick the exact position occupied by the station with sufficient accuracy for

photogrammetric purposes. A lone tree is not as desirable a picture point as the intersection of the centerlines of two intersecting roads or a sharply defined property corner. Although a lone tree may appear as a small point at the scale of the photography, it must be borne in mind that in the enlarged views later studied under the stereoscopic plotting instruments the lone tree may become a sizable object and it may be difficult to set a mark precisely on the point selected in the field. The precision required in pricking points is called for not only for the purpose of keeping planimetric detail in its true geographic relationship but also to assist in the establishment of true elevations in vertical control extension work where the horizontal position of a point is used as an aid in the absolute orientation of multiplex projectors. It is a necessary practice to select only picture points which can be located most precisely by the photomapping company, and to prick them very carefully so that this control can be used if necessary as a positive aid in extending vertical control with the multiplex equipment. Since it is almost physically impossible actually to prick the point precisely enough in the field (to within 0.1 mm of its true location) to satisfy the purposes outlined above, an enlarged and detailed sketch should be submitted showing the location of the point that was intended to be pricked. The actual pricking of the point should be done with a needle point pricker, and the prick mark should be made just deeply enough to penetrate the photograph so that the description of the point and the data for it may be placed on the back of the photograph and referred to the prick mark. On a rush job the enlarged sketch, the coordinates of the points, and their elevations may all be placed on the reverse side of the photographs and submitted in that form. For routine operations it is desirable to use a regular transmittal form (fig. 8) in transmitting field control data. In this case the photographs should show the pricked points and their numbers or designations and be submitted along with the transmittal form.

b. In connection with the selection of good picture points it should be borne in mind that identifiability is of primary importance, position on the plate pair next in importance, and the use of a good tactical feature third in importance. It is desirable to have critical elevations wherever they can be procured without too great difficulty, even when the point whose elevation is determined cannot be pricked. The elevations of hilltops, saddles, stream junctions, the average heights of trees in woods, etc., should be procured whenever possible incidental to the establishment of the absolutely essential control.

DESCRIPTION OF PICTURE POINT

QUAD San Jose INDEX N3715-W2145/15
STATE Calif. COUNTY San Jose

DESIGNATION OF POINT PP 1/32 ESTABLISHED BY Co. "A", 29th Engrs. YEAR 1940

TRAVERSE NO. 32 FIELD BOOK NO. A-1-32

PROJECT San Francisco. STRIP 23 CHIEF OF PARTY Carlton

PHOTO B 405 & B 406

DETAILED DESCRIPTION OF POINT: San Jose, 60 miles north of;

Alviso, 3.1 miles east of; along Alviso - Warm Springs Road, at intersection of Route 17 and Alviso - Warm Springs Road.
P.P is 32 ft. north of station - 75, traverse 32.
P.P is the intersection of the center lines of roads Route 17 and Alviso - Warm Springs Rd.

3 ORDER POST. NA 1927 LAT. 37-18-19.186 LONG 121-54-13.971

4 ORDER ELEV. 121.9 ft. 1929 GEN. ADJ.

FIELD SKETCH

SYMBOL ●

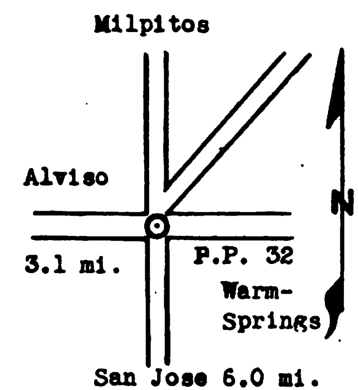


FIGURE 8.—Transmittal form for field control data.

②

FIGURE 9.—Plate pair with six picture points marked for control by field party.

c. Great care must be exercised in the computation and submission of field control data. A system of double or triple checking should be used to avoid the possibility of any type of error, because errors in field control data delay the work in the photomapping company out of all proportion to the time which might have been required to insure correctness in the field.

Figure 9 illustrates a typical plate pair showing the selection of picture points for its control. The reverse side of one of these photos (fig. 10) indicates the designations of the picture points for which the data are normally submitted on a transmittal form such as shown in figure 8. On an urgent job the data may be submitted on the reverse side of the photograph. (See par. 75, TM 5-230.)

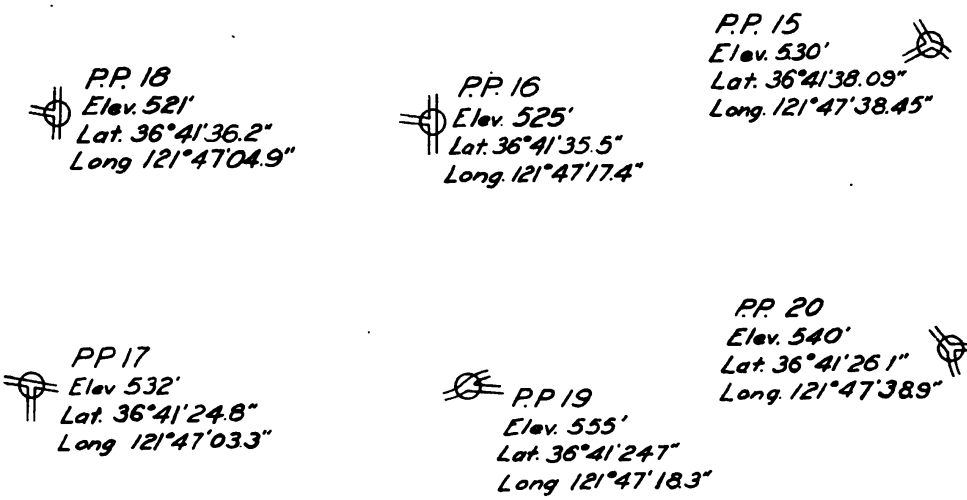


FIGURE 10.—Rear side of photo showing enlarged sketches indicating location of picture points and including designations and control data. Only the designation need be shown when a transmittal form is submitted.

SECTION III

PROJECTIONS

17. General.—For normal military mapping purposes the polyconic projection is used. Over this projection is superimposed a military grid. The projection should be placed on a medium of limited distortion characteristics, such as a nonshrink acetate, metal, or wood. A carefully enameled 5-ply or 7-ply plywood board will be found satisfactory. It should be painted all over with two coats of

paint to limit moisture loss or absorption, and the working surface should be carefully prepared with a hard drying white enamel upon which lightly etched lines will be visible.

18. Polyconic projections.—The projection will be laid out in accordance with instructions contained in Special Publication Number 5, United States Coast and Geodetic Survey, entitled "Tables for a Polyconic Projections of Maps." The longitude and latitude intersections will be represented by tick mark intersections or colored lines.

19. Military grid.—*a.* The military grid will be superimposed over the polyconic projection in accordance with data taken from Special Publication Number 59, United States Coast and Geodetic Survey, on "Grid System for Progressive Maps in the United States." Beam compasses and calibrated invar bars should be used in making measurements which should be within $\frac{1}{200}$ of an inch. Intersections should be scratched on and blackened later with ink after check has been made by a second projection lay-out crew. Magnifying glasses should be used liberally during the construction of the projection. Since the projection is the foundation of the map and will affect all work to follow, it may, if carelessly made, seriously retard progress or reduce the map's accuracy.

b. The projection board for multiplex mapping should be large enough to cover the project or an integral portion of the project. For instance, it is convenient to prepare projection boards to cover the area of a 15-minute quadrangle within the United States. When the radial line plot is to be used in conjunction with multiplex mapping, an additional projection covering the entire area of the project should be prepared if possible. The scales of these projections to be used will depend on the optimum plotting scale of the multiplex and the scale of the photographs. For radial line purposes the scale of the projection should be approximately the scale of the photography, which for pictures taken from 20,000 feet with a 6-inch focal length multiple lens camera will be approximately 1/40,000, depending on the average height of the terrain. With the multiplex projection board, for the same type of photography, the scale will be approximately 1/16,000.

20. Plotting control.—When the projection has been constructed, field control may be plotted thereon using normally the transmitted geodetic coordinates computed by the survey company. Control previously established by other agencies and for which published data are available will likewise be plotted. Great pains should be used in this operation and the work should be subjected to an independent check.

There should be available scales finely graduated and adapted to the projection being used. With a normal multiplex projection plotted to minutes of longitude and latitude, the scale may be used as a proportion guide to divide each minute into seconds and decimals of a second as shown in figure 11.

Using the rule so that 60 units are subtended by the parallels, the latitude may be plotted, such as 37°47′25″, and a dot pricked to indicate this plot. This operation should then be repeated a short distance away and a line scratched joining the two dots. Longitude may be plotted similarly by placing the rule to cross meridians. The plotted position of the point will be represented by the intersection of the

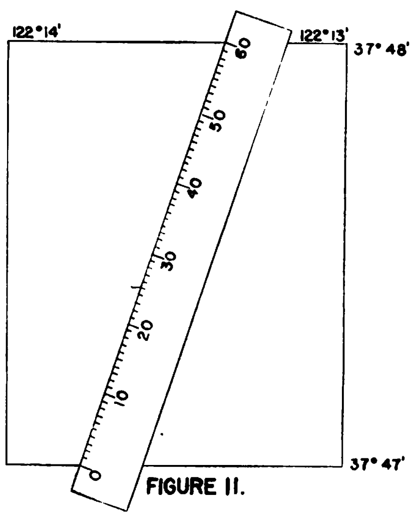


FIGURE 11.

two scratch lines. This intersection is next marked by a needle prick under magnification and numbered and designated as indicated on the transmittal form with elevation also recorded directly on the projection and near the plotted point. When all available field control has been plotted to the projection, the information available thereon is ready for transfer to multiplex work sheets. If a radial line plot is to be made, the projection will be at the scale of the pictures, and after all field control has been plotted, the projection is ready to be used directly as a base for a slotted templet plot described in paragraph 53, the radial line plot with individual templets described in paragraph 52, or information may be extracted therefrom for a radial line plot as covered in paragraph 51.

SECTION IV

ADDITIONAL PROCEDURES

21. Radial line plot.—When it is considered desirable to use a radial line plot in conjunction with the multiplex mapping method for the purpose described in paragraph 7, this plot may be made as described in paragraphs 51 to 53, inclusive. Briefly, such a radial line plot may be used to good advantage in establishing the horizontal control net where the available field control is scarce or on one end of the project only. This will assist the multiplex extensions by establishing scale and by fixing horizontal motions of the multiplex projectors. Where the extensions are not too long, the advantage in time will be in favor of using the multiplex alone.

22. Printing diapositives.—Just as soon as the negatives have been received in response to requisition on the Air Force as described in paragraph 12, the diapositives to be used may be printed. Normally one set of diapositives providing complete stereoscopic coverage of the area involved in the mapping will be sufficient. When equipment and personnel available permit and the mapping project is of an emergency nature, two or three sets of diapositives may be printed, one set for control extensions and two sets for plotting so that the entire area may be plotted by a number of operators working simultaneously without interference, as soon as the necessary control has been made available. These diapositives should be made in accordance with instructions contained in the Multiplex Operators Manual. This is a photographic process involving the printing from the original negatives to small glass plates (diapositive plates) in a special reducing printer designed for the camera used so that there will be a true reproduction through the multiplex projectors which have a fixed focal length. One of the reducing printers used is shown in figure 12.

23. Preparation of work sheets.—As soon as the projection has been completed and all control plotted thereon, the work sheets for

FIGURE 12.—Reduction printer for printing diapositives from 6-inch focal length camera.

multiplex operators can be prepared. Use a high grade vellum of nonshrink characteristics, which has been permitted to hang in cut sheets for several days if possible. The data from the projection are traced directly to the work sheet when the projection is at the plotting scale. In this step great care is taken in copying the data precisely. The intersections of grid lines are extracted from the projection and numbered sufficiently to permit reorientation on the projection board after the plotting is complete. Operators working on control extensions extract data on a continuous strip for the length of the extension and the width of a stereoscopic model. Those working on individual plate pairs or groups of plate pairs extract all information pertaining to the area involved directly from the projection or from the work sheets of control extension operators when the latter have finished or progressed far enough to supply sufficient information to permit absolute orientation of pairs of projectors. If the original projection has been made to the scale of the photographs to permit the making of a radial line plot, the resulting data on the projection must be changed to the multiplex scale. This normally means that data on the projection must be enlarged about 2½ times. This may be accomplished by scaling and computation, by pantographing to the plotting scale, or by using enlarging or reflecting projectors. The use of enlarging or reflecting projectors is most desirable to insure accuracy in this difficult step wherein errors made on the original board are multiplied as a rule about 2½ times in the enlargement. An example of a reflecting projector is shown in figure 13. For work eventually to be plotted entirely with the multiplex equipment it is desirable to have separate projections drawn to the plotting scale, so that field control and grid lines may be precisely plotted and provide a good base on which radial line control may be added. With the information available plotted on the work sheets, inked, and marked for identification, the multiplex operators may proceed with their control extension or individual plotting.

24. Multiplex mapping.—The extension of vertical control and the plotting of individual plate pairs is accomplished in accordance with instructions contained in the Multiplex Operators Manual. If the project is one where speed is all important, control extensions are carried on to supply vertical control for each plate pair, this control to consist of approximately six well distributed points in each plate pair. When a plate pair has been controlled, the information as to the points controlled is transferred to the photographs involved as well as plotted on the work sheets. Using these data and a separate set of diapositives, individual operators can complete the plotting of plate pairs in pencil. For photograph interpretation see

FM 21-25, FM 21-26, and FM 30-21. Oblique plate pairs may be plotted only after control has been secured along the edges of the B plates of the two flights which overlap on the obliques involved. Using the two lines of control transferred to the oblique plate pair from

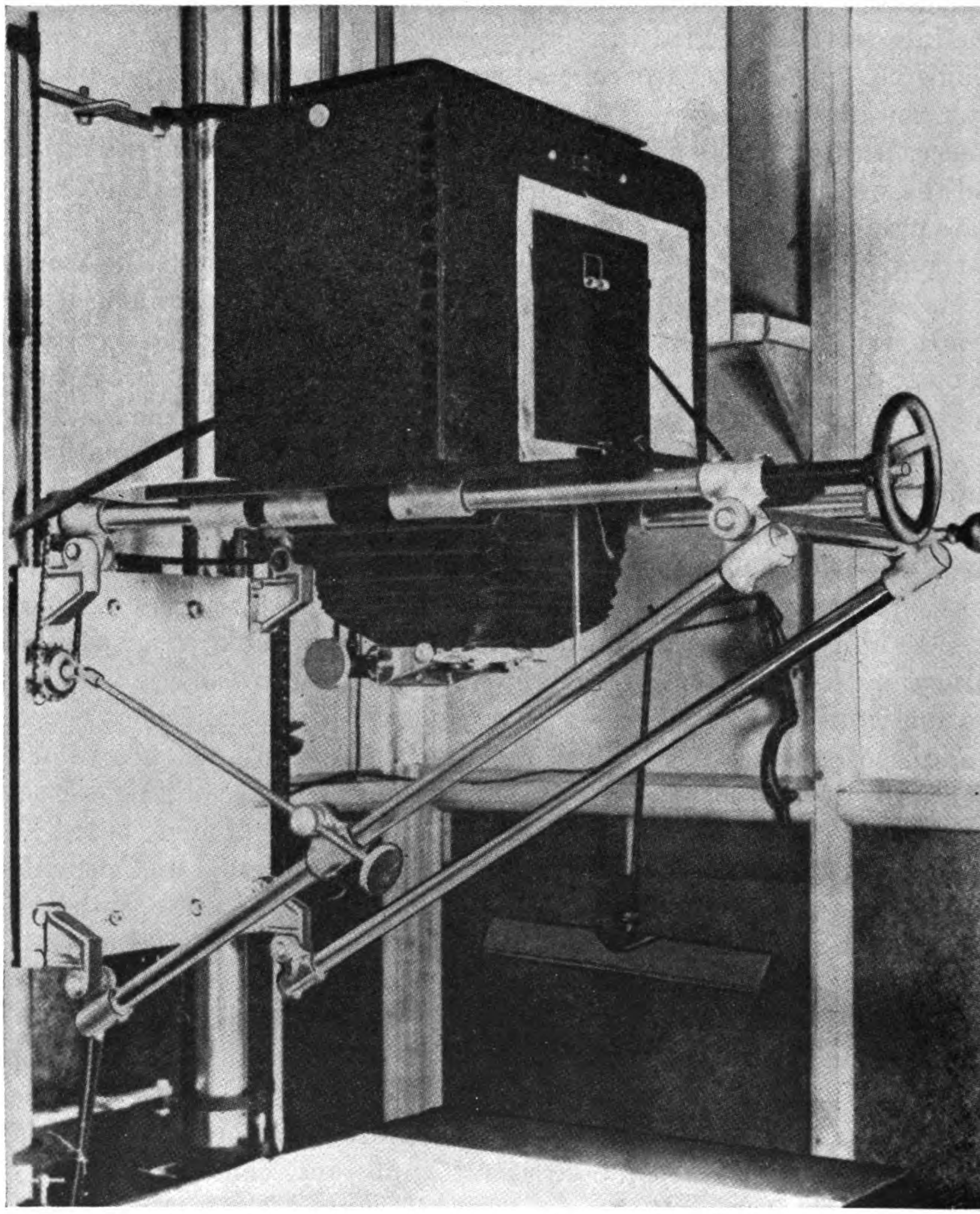


FIGURE 13.—Reflecting projector.

the overlapping B plates, individual operators may complete the plotting of these plate pairs. No control extensions may be performed with the oblique projectors. There are pictured herein (figs. 14, 15, 16, and 17) a few special instruments which have been found of

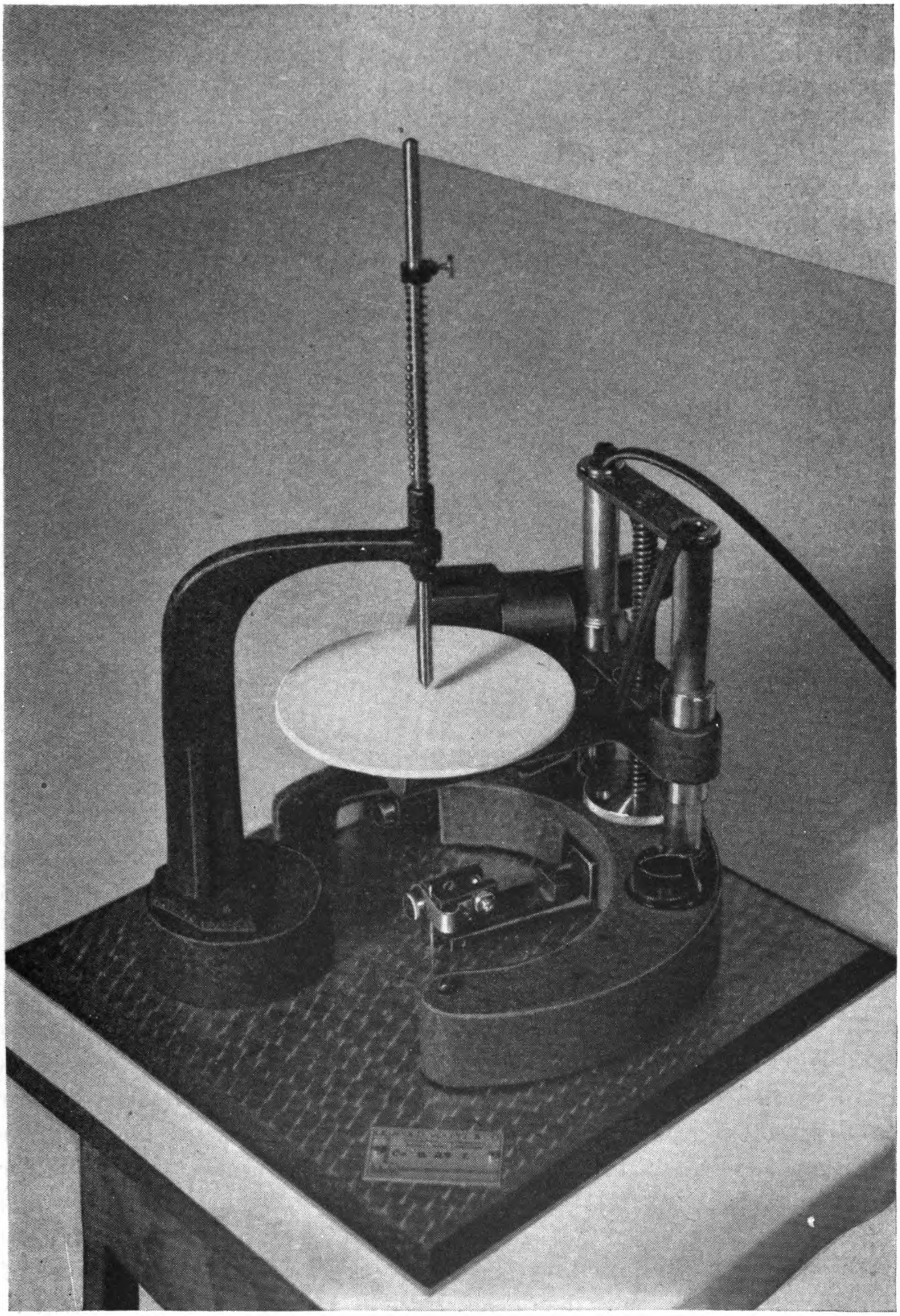


FIGURE 14.—Device for centering pencil point with floating mark of tracing table.

some help in the operation of multiplex equipment. The instruments include a special multiplex table level, a modified tip-tilt level, an improved height gage, and a pencil centering gage. There is also shown in figure 19③ a development model of a short multiplex bar in operation. This short bar designed for plotting only from controlled plate pairs may serve to release the longer bars for control extensions. It has been found economical in space required, highly portable, is readily fabricated and installed, and can be used to good advantage by individual operators in the plotting stage of multiplex mapping. The need for these instruments is covered in appendix I.

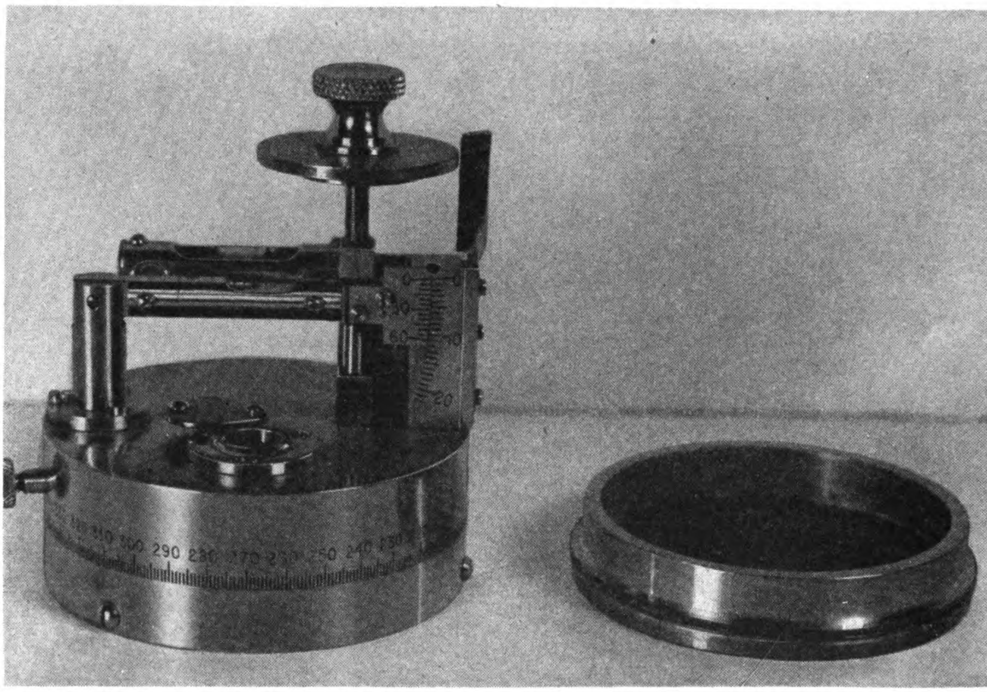


FIGURE 15.—Modified tip-tilt level, showing improvements to increase utility of the instrument.

25. Mounting of individual plots.—As the multiplex operators complete the plotting of plate pairs in pencil, they notify the section head who checks the work before removing it and then turns it over to draftsmen who ink the individual plots. Inking by separate draftsmen releases the multiplex equipment more promptly for additional plotting. It also permits an additional editing stage wherein an independent draftsman studying the plot and the photographs may correct obvious errors or call for major corrections of detail. When the work has been inked it is mounted on the projection board by means of the control transferred from the projection to the work sheets and the grid line intersections. This may be done

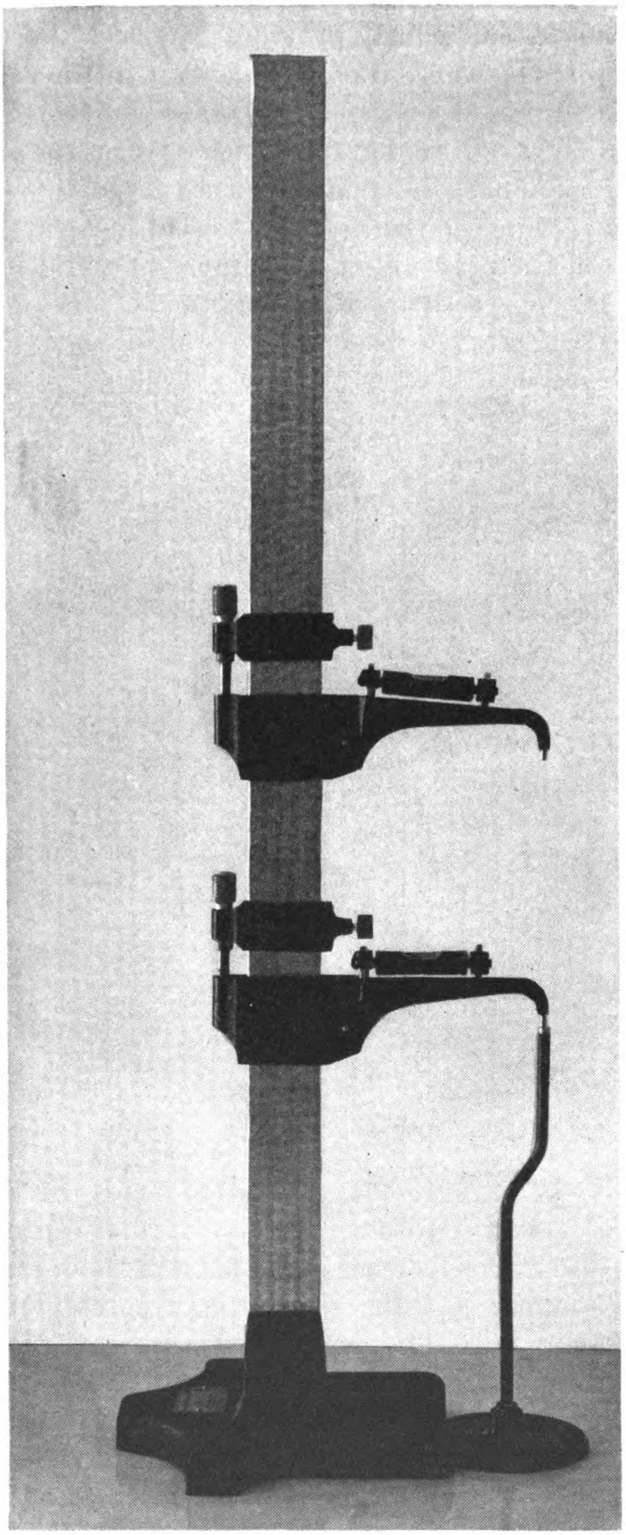


FIGURE 16.—Special design height gage with its calibrating gage. Used for making simultaneous measurements from multiplex table top to tracing table and to top of diapositives.

best with rubber cement. Overlapping individual plots are matched by cutting along a line which provides the best junction between the individual plots or where the match is best in the area worked in common by the different operators. The area of overlap of work sheets prepared should be about 1 inch wide to insure a good match. When all the individual plots have been mounted to the projection, final inking, correcting, and editing are accomplished. A portion of a typical multiplex manuscript in two stages of completion is shown in figure 18. Two views of multiplex equipment are shown in figure 19① and ②.

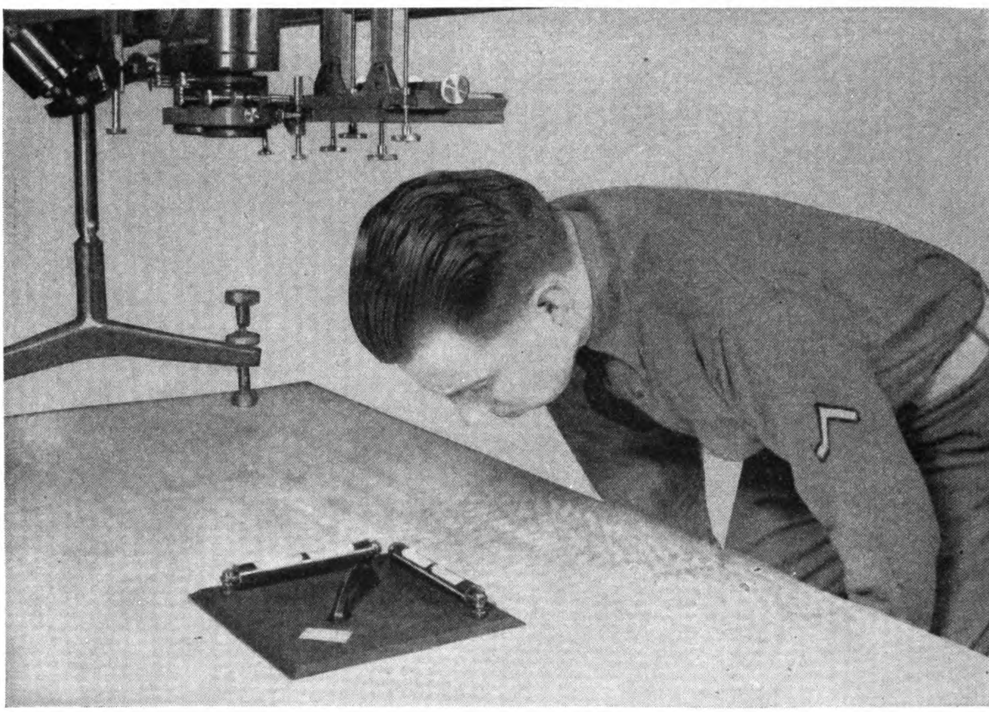
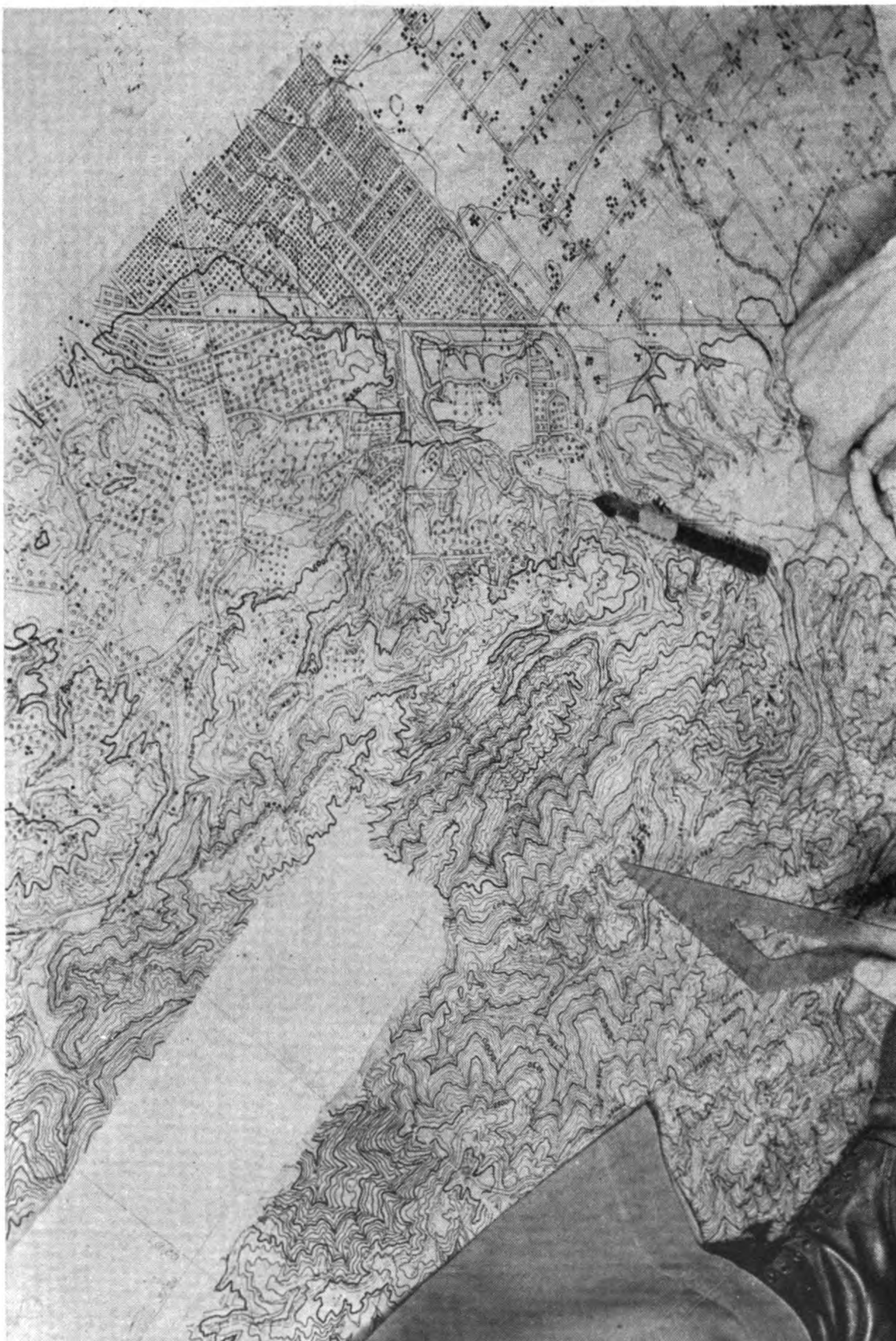


FIGURE 17.—Leveling multiplex table with special level.

26. Editing.—A careful edit should be made of the completed multiplex manuscript so that, if necessary, one-color reproductions may be supplied for use by the field forces. This edit should include a careful study of the manuscript for topographic representation, registration of hydrography with topography and culture, the inclusion of all important cultural detail, the accuracy and completeness of woods symbols, the numbering of contours, the representation of field control and spot elevations of important military features, and the sizes and types of conventional signs. For normal projects destined to be reproduced at a scale of 1/62,500, while the manuscript is at a scale of approximately 1/16,000, a model chart should be provided which shows the sizes of

① Portion of multiplex manuscript made up of several individual sheets mounted on projection board. Gap to be filled in by additional plots.

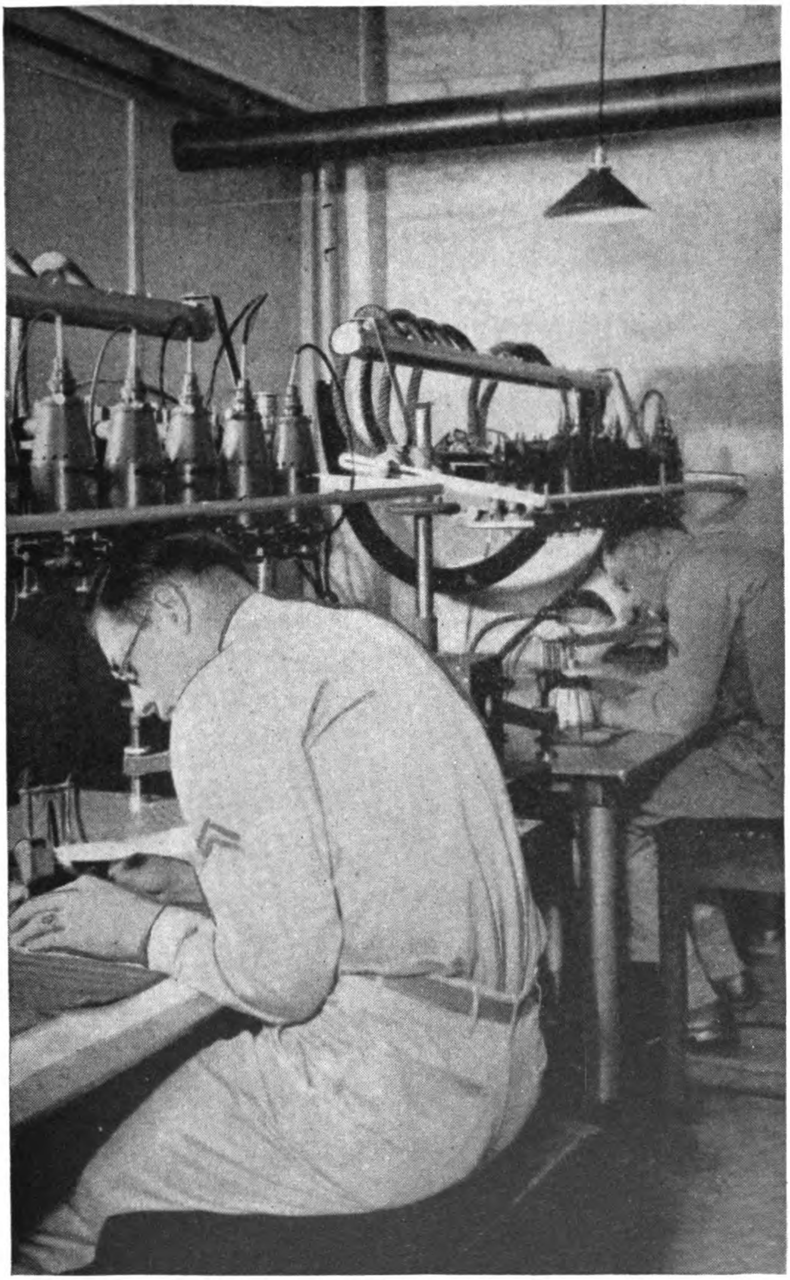
FIGURE 18.



② Same portion of multiplex manuscript with gap partially closed by adding another individual plot.

FIGURE 18.—Continued.

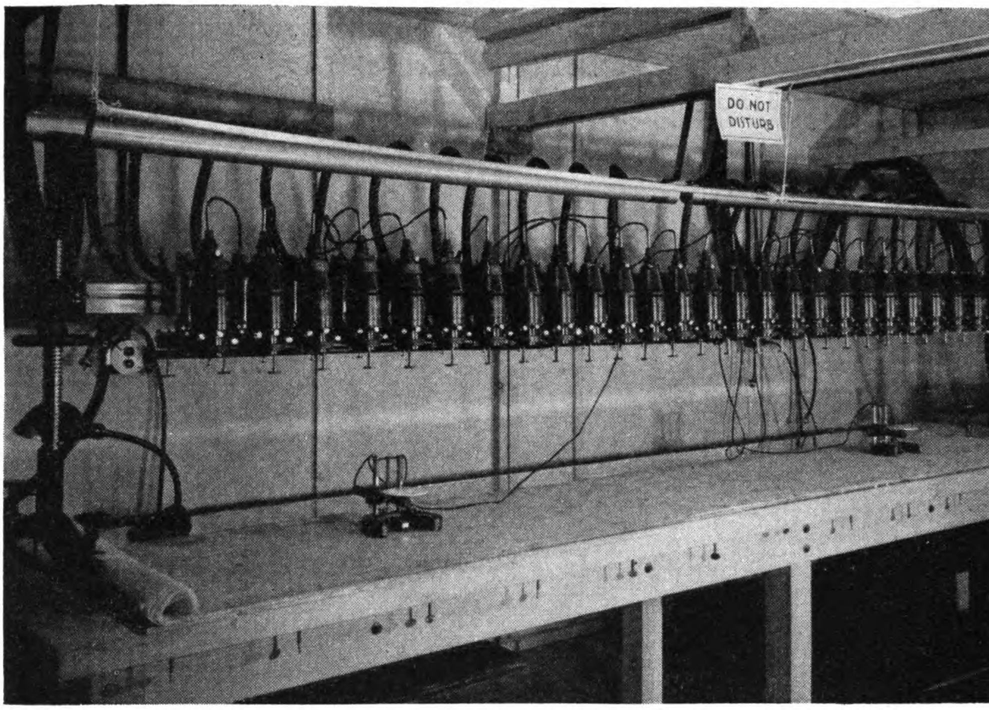
conventional signs required to produce a conventional sign of the proper size and reproduction scale. This model chart may be made by simply enlarging conventional signs from acceptable maps to the scale of the manuscript.



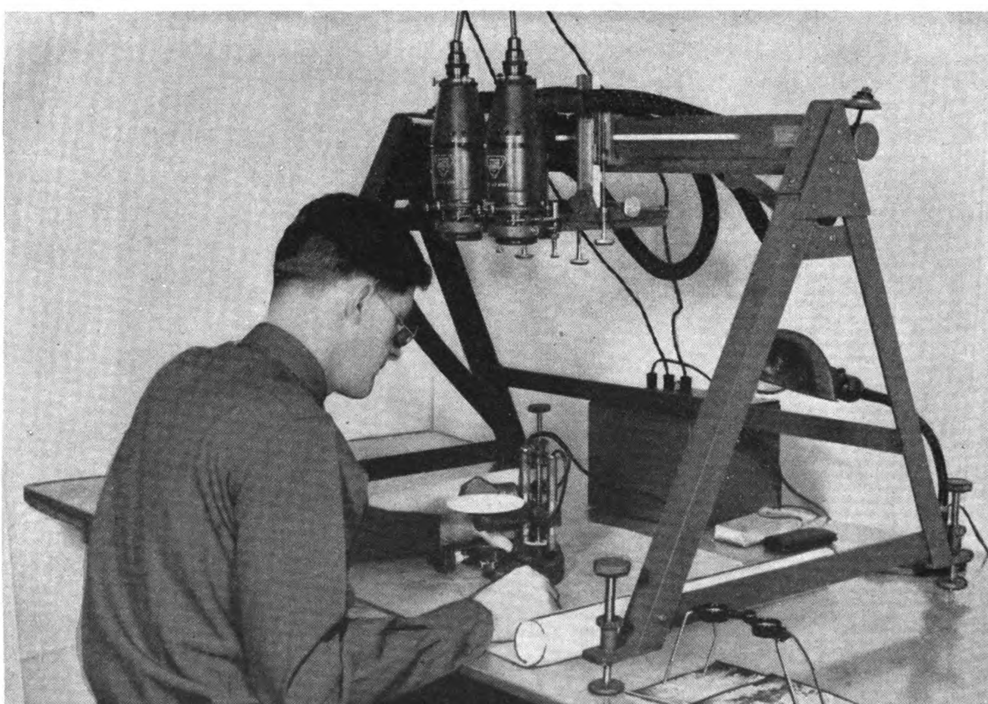
① Multiplex in operation. Two nine-fold bars in one booth.

FIGURE 19.

27. Hasty reproduction.—The type of reproduction involved in publishing the map will govern the next step. If a one-color map is



② Double multiplex bar arranged for long control extensions.

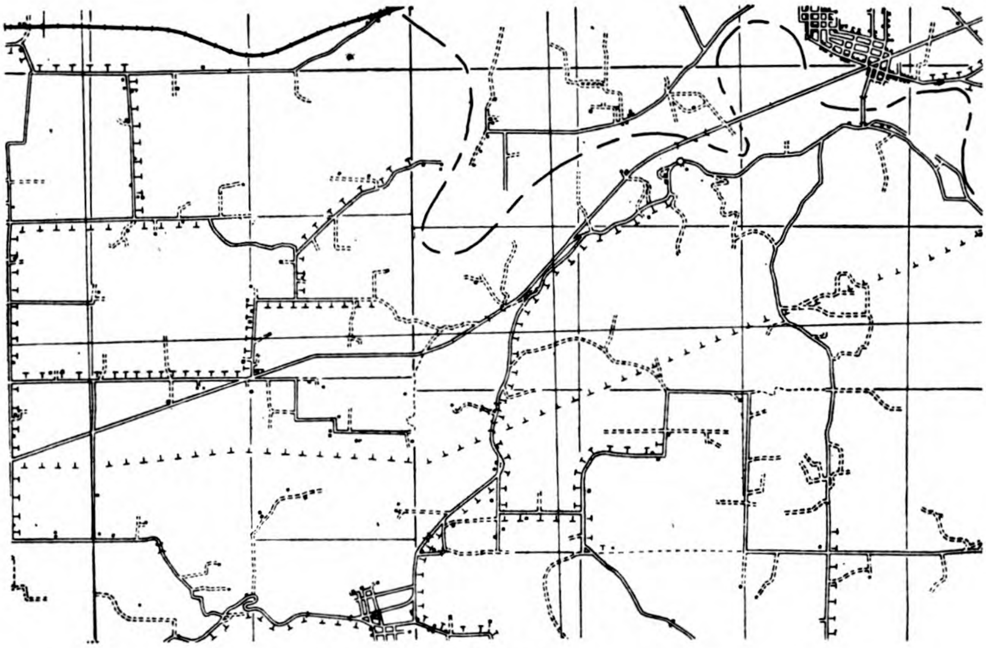


③ Short multiplex bar in operation ; a development model for plotting only.

FIGURE 19—Continued.

desired in the shortest possible time, the manuscript, with marginal data and such names as are available, is turned over to the reproduction company for final reproduction at the desired scale. Maps so reproduced will lack refined drafting, may be minus important names, and show incorrect road classification, due to the fact that a field check has not been made. Furthermore, if the manuscript was drafted for direct reduction to 1/62,500 and a larger scale is used, the symbols will be exaggerated. If time permits, publication may be made in two or more colors or float symbols may be used to depict woods. When there is a forewarning that reproduction is to be in one color, special means may be taken in drafting the manuscript, such as intensifying culture and streamlines and subduing contours, so that the one-color reproduction will be more legible. When there is sufficient time available, the reproduction is made in several colors, as indicated in the paragraphs below.

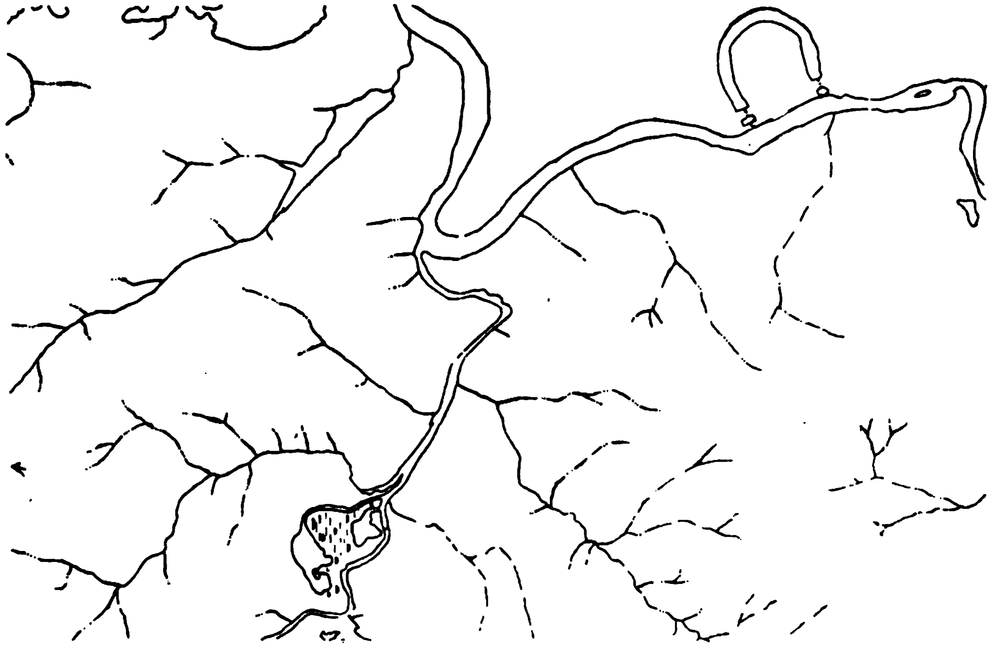
28. Blue line sheet preparation.—With a completed manuscript of a 15-minute quadrangle, edited as in paragraph 26, now available, there remains the problem of reproduction in several colors. This reproduction may be a scale of 1/20,000 or 1/62,500 for normal work. For a reproduction at a scale of 1/20,000 a slight reduction in the scale of the manuscript will be involved, and since the conventional signs on the manuscript were of a size designed for reproduction at 1/62,500, it may be desirable in the final drafting to reduce the sizes of conventional signs. When one-color reproduction is acceptable, at a scale of 1/62,500, a photographic negative made with a precise copy camera and to the reproduction scale can be made by the reproduction unit. A negative at a scale of 1/20,000 may also be made, but conventional signs will be larger than necessary. A separate name sheet covering all names and marginal data should be prepared. It is necessary also to prepare color separation drawings. This may be done by first preparing blue line sheets, one for each color, and re-inking on each one, in black, only those features which are to appear in the same color. The blue lines not re-inked in black may be bleached out, although this is not essential when the blue is nonphotographic. Each plate is then ready for photography and the preparation of lithographic plates. Paper mounted on metal and coated with blue print solution may be used in the preparation of the blue line drawings. Painted metal sheets have been found to possess many advantages for average draftsmen as a base for the blue line drawings. Painted metal sheets are prepared by thoroughly cleaning with a grease solvent or graining No. 26 gage or heavier galvanized iron sheets of the proper size and painting with four coats of high quality white enamel which dries hard. After drying, the painted sheets are rubbed down with Bon Ami soap, washed, dried, then sized



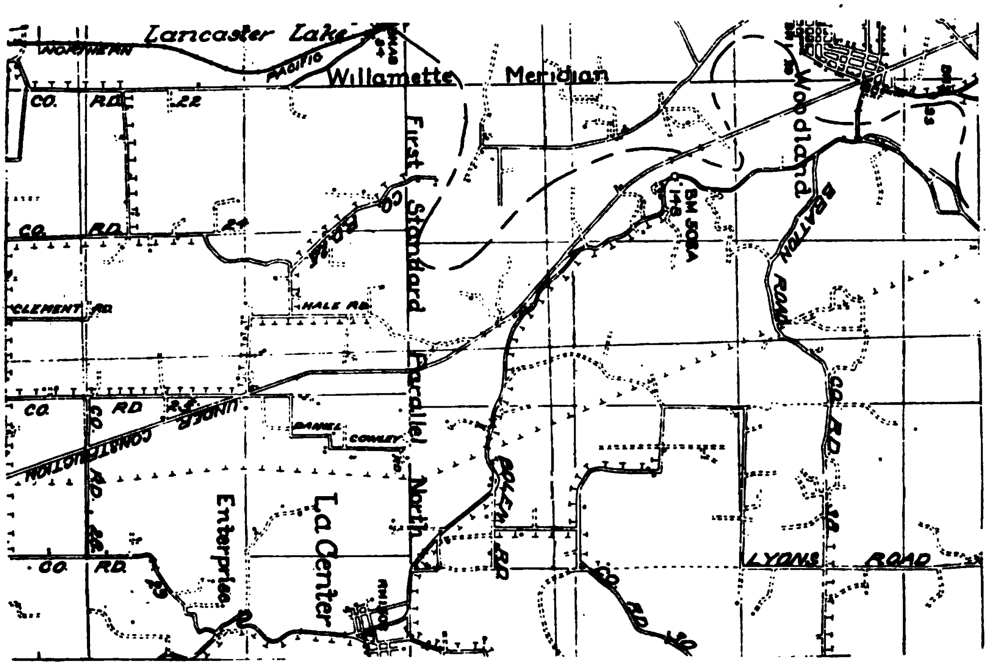
① Culture.

② Hypsography.

FIGURE 20.—Color separation drawing.



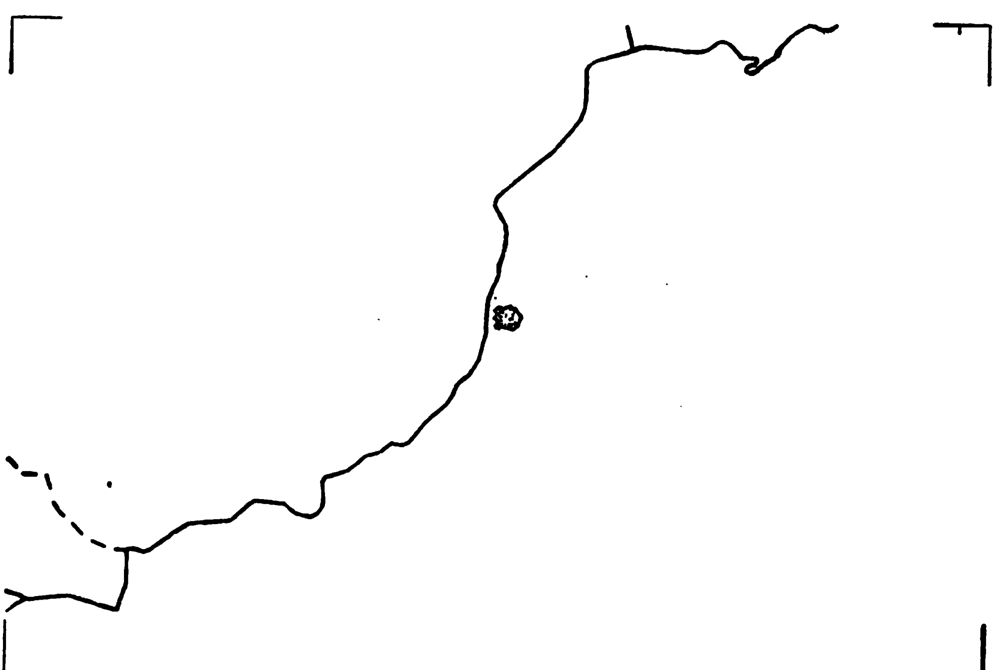
③ Hydrography.



④ Names.

Figure 20.—Color separation drawing—Continued.

⑤ Woods.



⑥ Main routes sheet.

FIGURE 20.—Color separation drawing—Continued.

with an albumen solution (1 part albumen, 60 parts water). Before sizing and sensitizing the sheets, they should be warmed in hot water so as to form a more receptive surface for the sizing and emulsion. The sizing may be applied with a wad of absorbent cotton saturated with the albumen solution, holding the sheet on edge to insure draining. Blue print solution freshly made and warm may next be applied with a camel's-hair brush with the sheet in a horizontal position. This solution consists of 1 ounce citrate of iron and ammonia, ¾ ounce red prussiate of potash, and 8 ounces of water. The two chemicals should be dissolved separately in water and then mixed. The emulsion should be force dried with hot air fans and exposed in a regular blue print frame in contact with the negative of which a blue line print is desired. Two 3,000-watt arc lights at 3 feet distance are required to secure a satisfactory print in approximately 30 minutes exposure time. A cooling fan should be used to keep the negative from sticking to the emulsion. After exposure the sheets should be washed in running water for about 5 minutes. The blue line prints thus made form a suitable base on which to make color separation drawings. They should be at a scale about 30 percent larger than the final reproduction scale. The painted surface takes ink well, erases easily, and takes corrections readily. Newly painted sheets should be used, as time-hardened paint may not take the sizing or emulsion solutions very well. Such sheets may be repainted and used again, if desired.

29. Color separation drawing.—With blue line sheets prepared, draftsmen are put to work on color separation drawing. Each draftsman draws in black on one blue line sheet only those features which are to appear in the same color. For example, one draftsman traces all cultural detail in black on one sheet, another the hydrography, a third the hypsography, and a fourth the woods. A separate tracing where necessary may be made for the name sheet and one for main traveled highways which are to appear with a red overprint. For the woods, float symbols of woods may be pasted on and cut out to the shape desired. Draftsmen follow the blue lines for size of symbols and weights of lines when the color separation scale is the one contemplated when the manuscript was prepared. Otherwise at this stage the draftsmen change the sizes of conventional signs and weights of lines to produce a proper result at the reproduction scale. For the inking of planimetric features, ruling pens of various types may be used as for any drafting, and for contour inking either a contour pen or a capillary fountain pen (fig. 21) may be used with good results. Examples of portions of color separation drawings are shown in figure 20.

30. Field check and edit.—In normal operations a field check of completed quadrangles should be made to pick up any gross misinterpretations of the photography, obvious errors or omissions, additional names for features, and road classification information. This

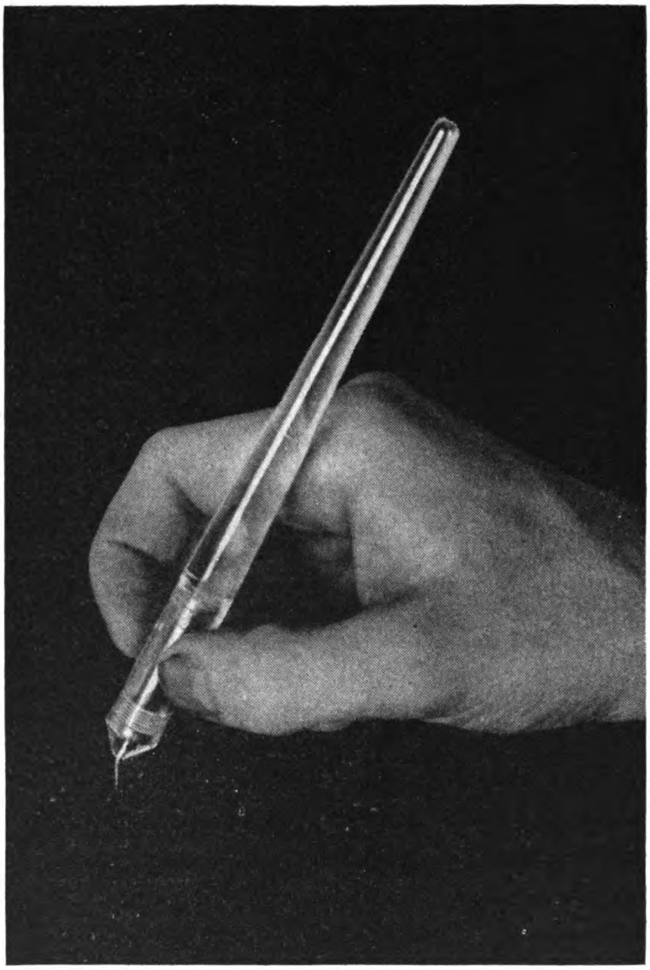


FIGURE 21.—Special capillary contour drawing pen.

information should then be incorporated into the color separation drawing by the final editors who go over each sheet with great care and correct errors or faulty draftsmanship. The map is then ready for reproduction.

CHAPTER 4

PROCEDURE BY STEREOCOMPARAGRAPH METHOD

SECTION I

PHOTOGRAPHY

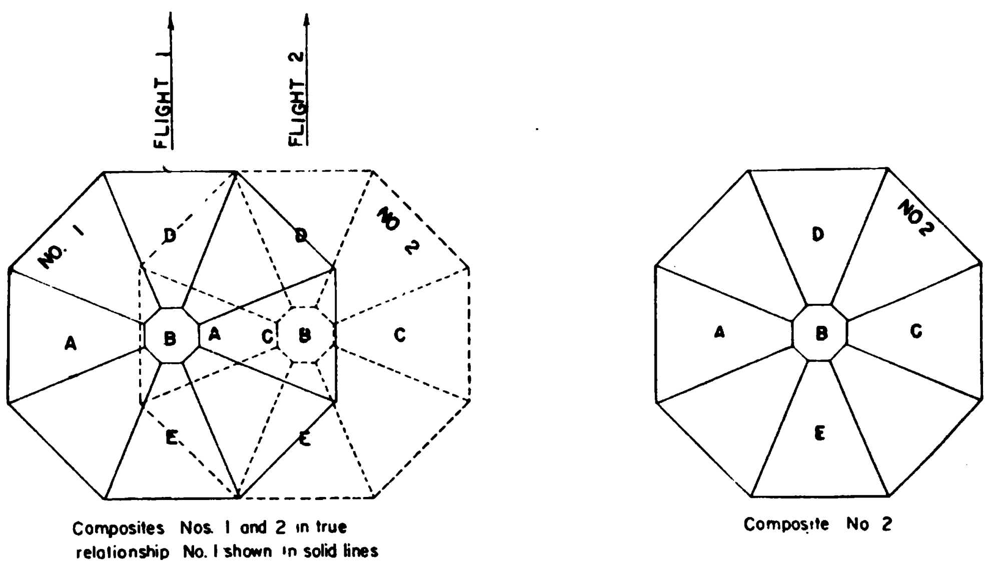
31. Selection of camera.—The selection of the camera is based on the same general fundamentals described in paragraph 9. However, the multiple lens or wide angle cameras have an advantage in the preparation of the radial line plot, and should be used in preference to the single lens camera for large projects.

32. Preparation of flight map.—As described in paragraph 10.

33. Specifications for photography.—As described in paragraph 11.

34. Selection of prints desired.—Considering only photography with the multiple lens tandem T-3A camera, it is desirable to make a careful selection of the desired contact prints, to check the adequacy of the photography, and later to provide a sufficient number of prints for use by the field survey unit, by the multiplex operators, by the compilers, radial line plotters, and stereocomparagraph operators. The selection should be carefully made so as to avoid the necessity of returning negatives later for additional prints and more especially wing prints for which the transforming printers are in the hands of the Air Force. Additional vertical prints can be made in any photographic laboratory equipped with a contact printer. As described in paragraph 12, quick prints of all the B or vertical photo-

graphs square to the line of flight and quick prints of wing pictures perpendicular to the line of flight and at each end of each flight should be sufficient for the purpose of checking the adequacy of the photography. With these prints available the overlap and the side lap can be checked as well as the clarity of the photography. As soon as these checks have been made and the photography is found satisfactory, a request can be submitted for the desired prints and negatives. Referring to figure 22 showing outline of two sidelapping composites, all of the B prints of all flights will be required for multiplex use, field use, and stereocomparagraph use. These B prints overlap 60 percent along the lines of flight and have no sidelap. To



NOTE.—In the sketches above only the wing prints of the camera which was squared to the line of flight are lettered. The wing prints of the other T-3A camera of the tandem mount bear similar letters. For use with stereoscopic plotting machines, all "B" prints, and all "A" and "C" prints will normally be required in this case. For compilation and radial line plotting, complete composites such that centers thereof will be from 6 to 8 inches apart along the lines of flight will be required.

FIGURE 22.

provide complete stereoscopic coverage suitable for use with the multiplex and stereocomparagraph, all wing prints perpendicular to the lines of flight will be required in most cases. These wing prints are lettered A and C in the sketch. When flight lines or photography along certain flight lines are so close together that the gap between the B prints can be covered by using one set of wing prints between the B prints, the opposing wing prints may be omitted. This requires that the gap between the B prints be covered by the portion of the wing prints only out to the collimating marks on these wing prints. To use the part of the wing prints out beyond the collimat-

ing marks is not often satisfactory for stereoscopic plotting purposes. For radial line plotting, compiling, and making map substitutes, photomaps, etc., a set of composites will be required such that their centers will be from 6 to 8 inches apart along every line of flight. An effort should be made to select composites so that those on each line of flight will be opposite each other and not diagonally displaced.

35. Requisitions for prints and negatives.—The request for prints should include one complete set of composites selected as above and printed on double weight glossy paper, double weight semimatte paper, or pigmented film base, and naturally dried. In this connection, caution should be given to use the same transforming printer on all wings, and this should be the printer which is designed to conform in scale to the B print which is to be used as the center of the composites. The B print of either camera may be used in printing composites if care is taken to use the corresponding transforming printer on all wings of the same composite. In addition, the requisition should call for three prints each on semimatte paper of all B prints and wing prints selected as in paragraph 12 for stereoscopic plotting, and the negatives of these same prints as soon as the printing has been completed. These negatives will be used in printing diapositives for multiplex use.

SECTION II

FIELD CONTROL

36. Recovery.—As described in paragraph 14.

37. Control lay-out.—As described in paragraph 15.

38. Selection, pricking, description, and submission of picture points.—As described in paragraph 16.

SECTION III

PROJECTIONS

39. Polyconic projections.—As described in paragraph 18. Projection is prepared at the scale of the photography.

40. Military grid.—As described in paragraph 19.

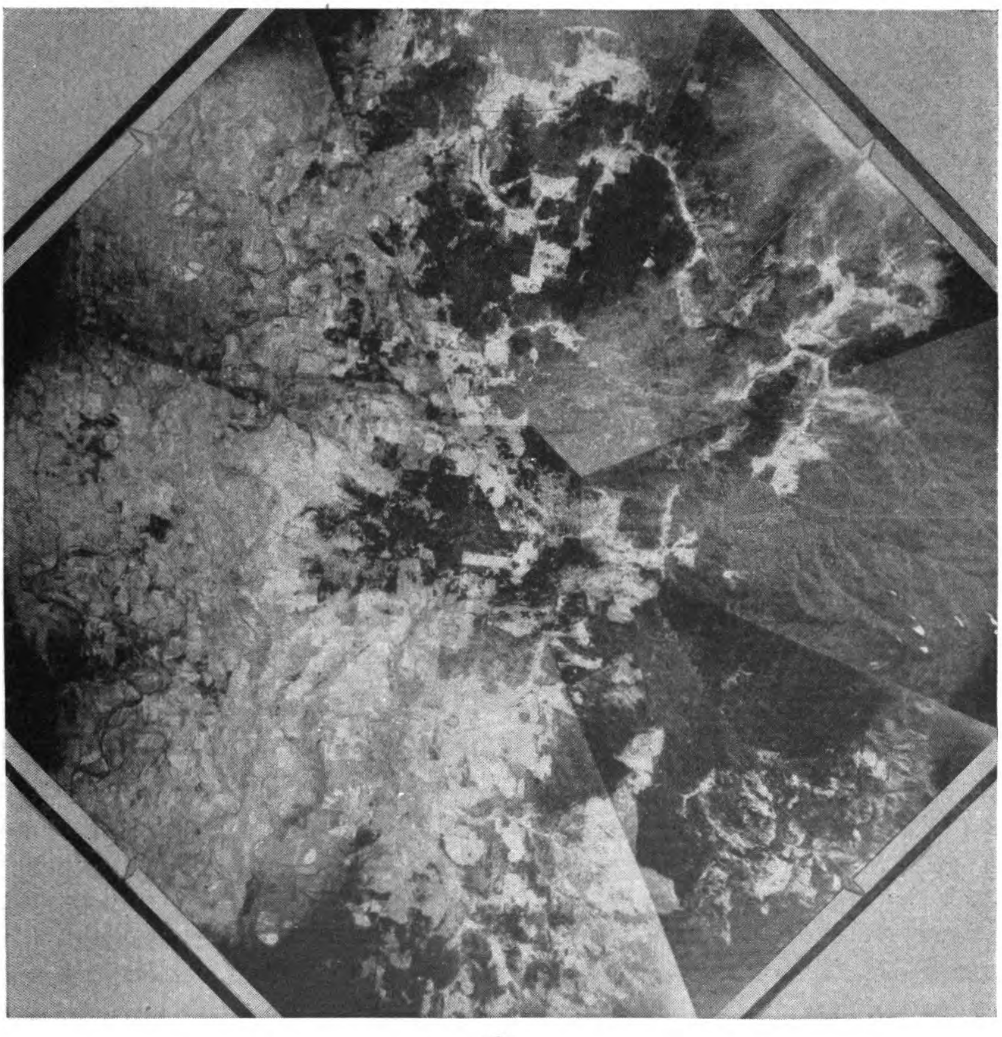
41. Plotting control.—As described in paragraph 20.

42. Enlargement to multiplex scale.—As described in paragraph 20. In preparing a map by compilation methods or whenever a radial line plot is used in conjunction with multiplex mapping to establish horizontal control, it is necessary to enlarge the data from the scale of the projection, which in these cases will be approximately the scale of the photography, to the working or plotting scale of the multiplex. This step may be taken whenever there is a sufficient amount of horizontal control established on the projection to serve as a guide for the multiplex operation, such as the control estab-

①

FIGURE 23.—Stereoscopic pair of composites from tandem T-3A camera.

lished by the slotted points in the slotted templet extension, or it may be done when all topographical points to a density of approximately one per square inch have been established on the projection. This will depend on the urgency with which the vertical control must be made available for topographical plotting. The enlargement to the plotting scale of the multiplex may be accomplished by the mechanics of scaling, mathematical computations and replotting to the enlarged scale on the multiplex work sheets, by pantographing to the work sheets, or by projecting the data from the projection to the work sheets through a projector which can enlarge directly to the multiplex scale. For a vertical control extension of considerable length, the data covered by the B prints in a line of flight may be extracted readily to a continuous strip of acetate by direct transfer



②

FIGURE 23.—Stereoscopic pair of composites from tandem T-3A camera—Continued.

from the projection. The strip of acetate may then be used under the pantograph or in the enlarging projector in the enlarging process. The use of a suitable direct enlarging projector or reflecting projector which can enlarge at least three and one-half times is probably the most accurate and unquestionably the fastest method for transferring the data to the multiplex work sheets at the proper scale.

SECTION IV

MOUNTING COMPOSITES

43. General.—The photographic prints received in response to a requisition as described in paragraph 35 are individual prints of the various camera chambers and these must be mounted by the photomapping company into the composite form of a photograph consisting of one vertical print and eight wing prints. See figure 23 for examples of composites. These composites are used as a base for the radial line plot, for compilation purposes, for photomaps, etc. They provide complete stereoscopic coverage of the area to be mapped with approximately 60 percent overlap along the lines of flight and 60 percent sidelap between adjacent lines of flight. This stereoscopic coverage is satisfactory for use under special prismatic stereoscopes or stereoscopes specially built to accommodate such large photographs, but cannot be used with the stereoscopic plotting machines now available.

44. Calibration of camera.—The calibration of the cameras used is originally accomplished by the engineer detachment at Wright Field, Dayton, Ohio. As a result of this calibration, a special metal alinement templet (fig. 24) is prepared with notches indicating the correct positions of the collimating marks on the outside and inside edges of the wing prints and on the B prints.

45. Trimming.—*a.* If the alinement templet fails to provide proper data for the mounting of composites, corrections may be determined by field recalibration when time does not permit rechecking of the camera by the engineer detachment at Wright Field. In this case, a locality is selected where there is a good observation station from which points can be seen all around the horizon. A field survey party may then determine the angles between a series of points such that at least one will fall far out in each wing print

of a composite with its center at the observer's station. Spot pictures are then taken with the camera to be calibrated so that the center will be as nearly as possible over the observer's station. Several pictures are taken, printed, and mounted with the points used as stations falling along rays radiating from the observer's station. The mean of several separate mountings will either confirm the calibrating data of the alinement templet or provide the corrections to be applied thereto. Trimming data may be determined, or corrected if previously furnished, at the same time. This involves a determination of the distances between the collimating marks on the sides of the wing prints and the trim line.

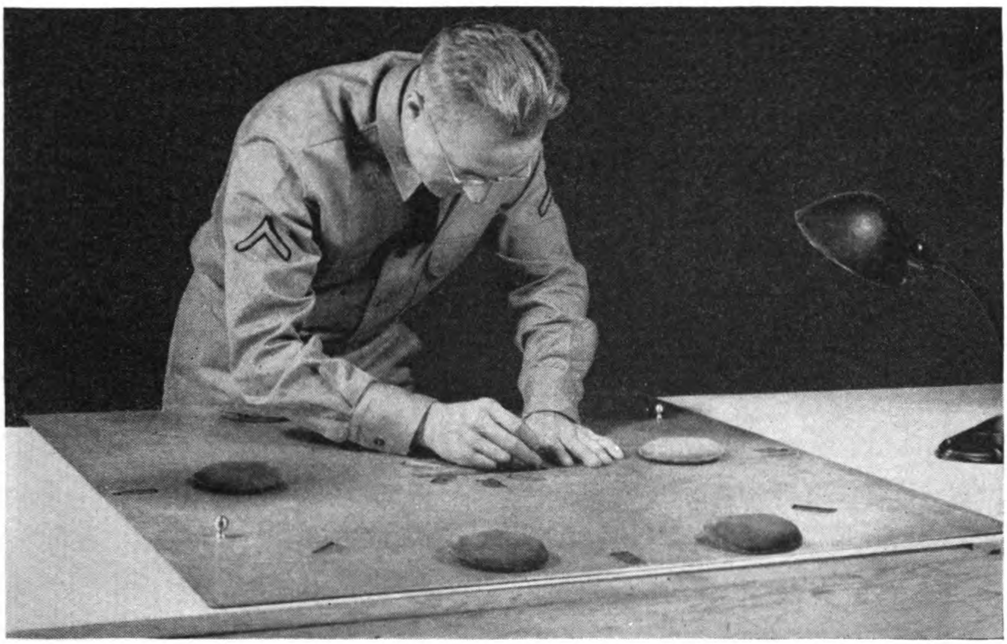


FIGURE 24.—Inscribing proper positions for collimating marks of various prints of a tandem composite, using alinement templet and masonite mounting board.

b. Using the alinement templet, lines may be inscribed on the medium on which the composite is to be mounted and the individual prints, after being roughly trimmed to the outside edge of the shadowgraph, should be pasted down so that their collimating marks match exactly these inscribed lines which also bear a reference to the wing print involved. This controls the position of the wing prints as to azimuth. In determining the proper position of the individual wing prints with respect to the B prints or, in other words, the trim line of the edges of the wing prints adjacent to the B print, there are two acceptable methods. The B print is trimmed with the assistance of a special templet of octagonal shape 137 mm between edges

which may be equipped with a special center pricking device to prick mechanically the exact center of the B print. This will be required later. (See fig. 25.) After trimming, the B print is ready for mounting and is pasted down with rubber cement so that its collimating marks match the lines previously inscribed from the alinement templet. The wing prints may be mounted by trimming to matched detail or by the use of special trimmers and previously determined trimming data, and then mounting to match collimating marks on the prints with inscribed marks on the mounting board. To use the method of trimming by matching detail, two identifiable points as far apart as possible in the area of overlap between the B print and a

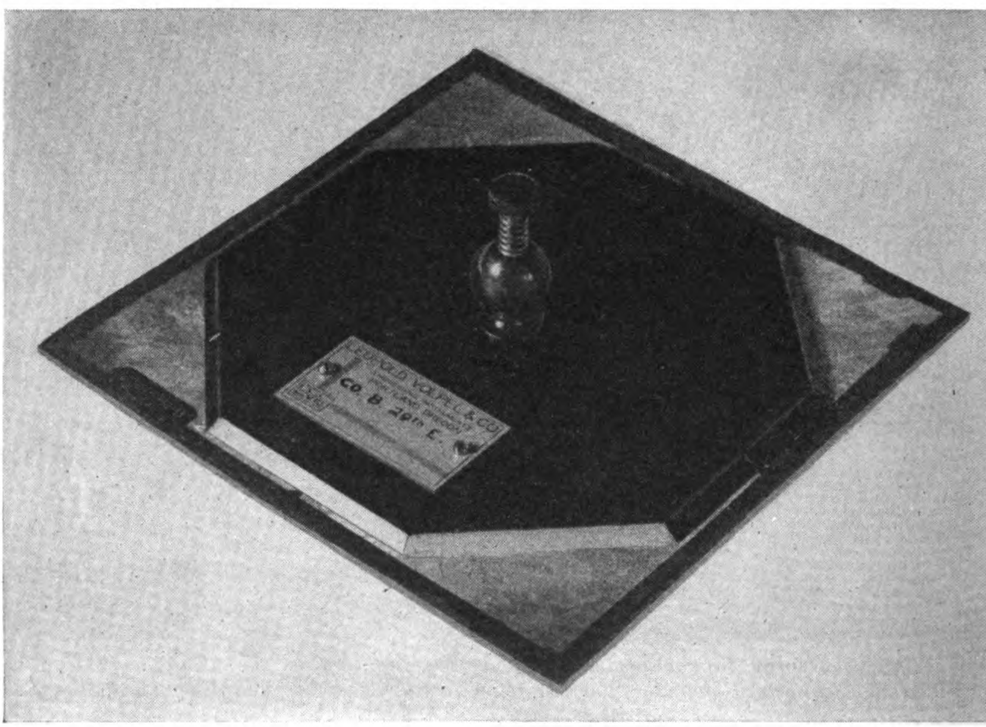


FIGURE 25.—Trimming templet for B print with center marking device.

wing print are pricked on both the B print and wing print, and both prints are then trimmed with a razor on a precise line between the pricked points. In this method the B print is not previously trimmed to octagonal shape with the aid of the B print templet. The disadvantage of this method is that it is extremely slow. It is preferable to use special trimmers with predetermined trimming data. Such data may be supplied with the alinement templet or determined by trial.

c. Several composites may be mounted as precisely as possible to match detail and the distances between the wing and B print colli-

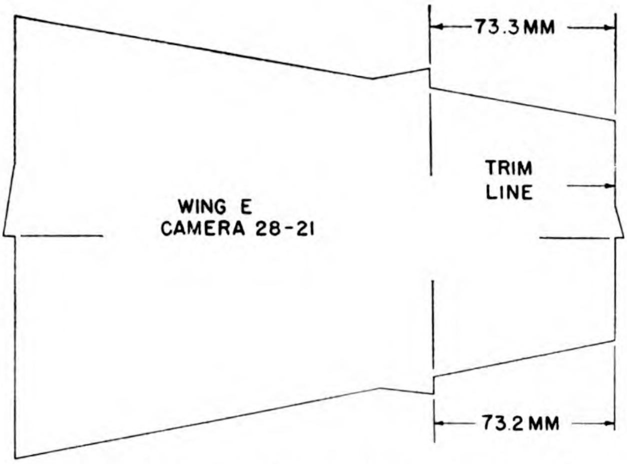


FIGURE 26.—Trimming data chart for wing print of composite. One prepared for each wing of each camera used.

mating marks carefully measured with a beam compass and invar scale. Subtracting the distance between the B print collimating mark and its trimmed edge (normally 68.5 mm), we have the distance from the wing print collimating mark to the trimmed edges. The mean of the several separate mountings may be used as the trimming data. These trimming data should be secured for each separate collimating

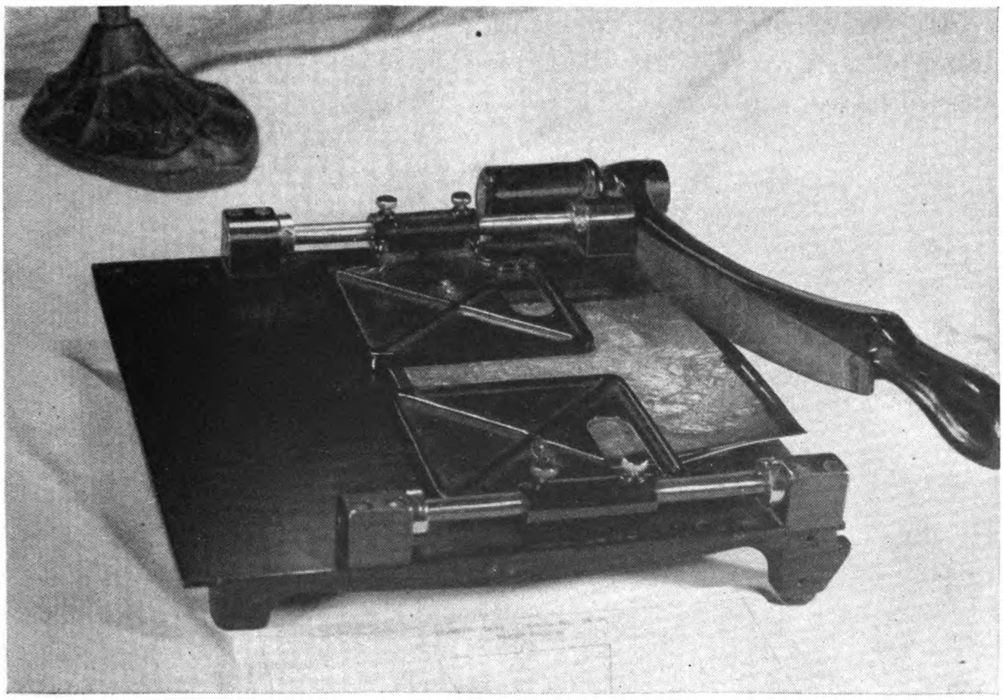
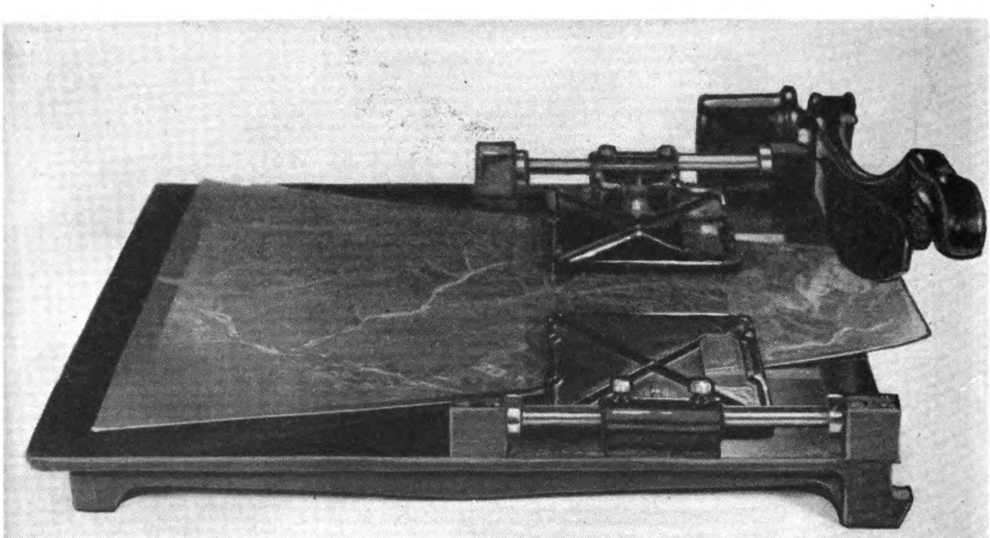


FIGURE 27.—Trimmer for B prints. Hairlines (not visible in photo) are oriented over collimating marks of B prints shown ready for trimming. Trimming data have been set off on scales inset in base of cutter, now partially hidden by photo.

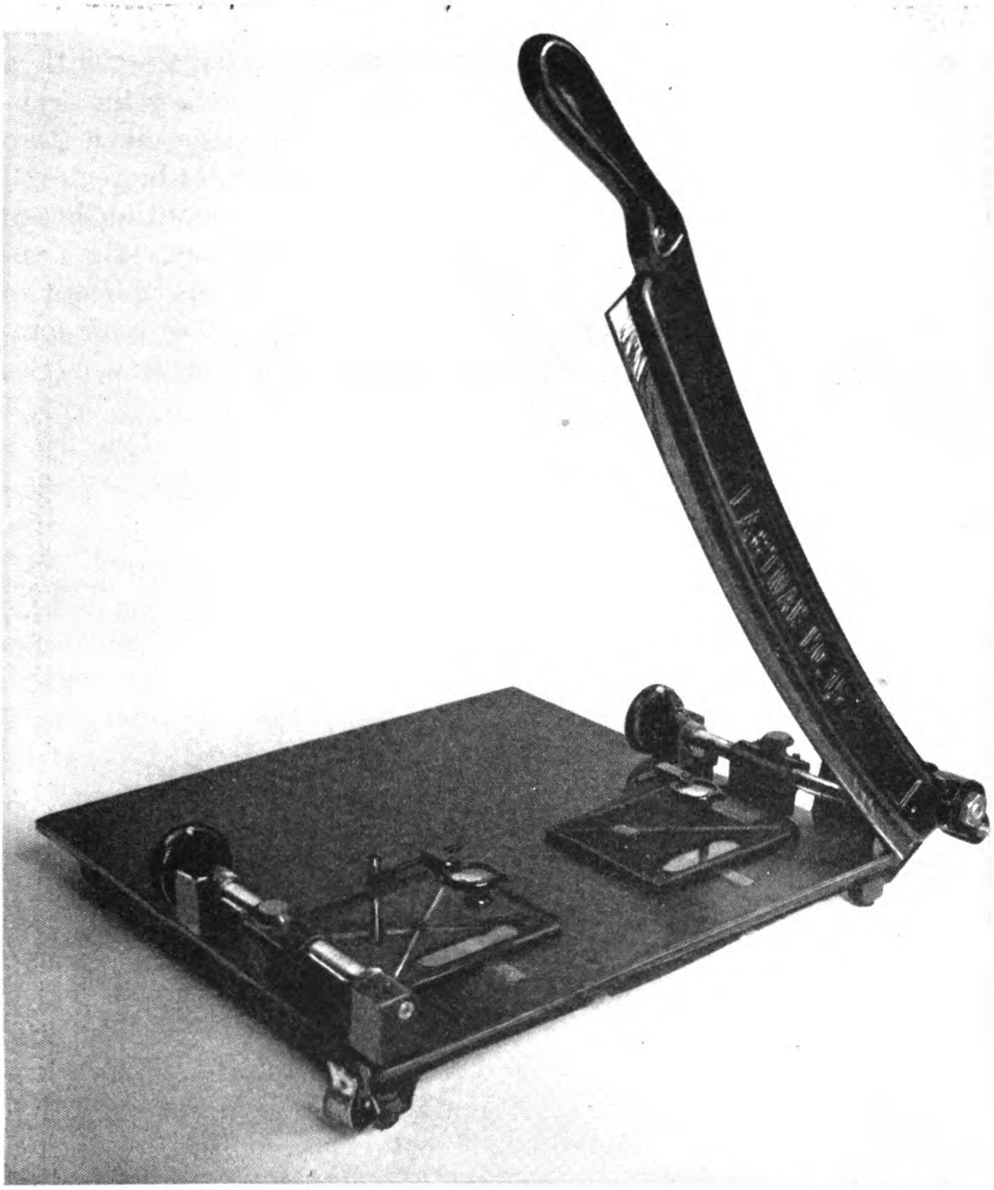
mark on each wing so that it may be set up precisely in special trimmers. It should be recorded in a diagram as shown in figure 26 for use by the trimmers. The trimming data can be set off on special trimmers shown in figures 27 and 28, and all similar wings trimmed by setting the wing collimating marks under the hair lines of trimmer windows. The vernier setting should be checked by measuring the length of cut on any sheet of paper with a beam compass. These trimmers are not precision machines and must be operated painstakingly to insure trimming correctly within 0.1 mm. Under artificial light, care must be taken to avoid errors due to parallax, and a magnifying glass should be used in making the initial setting. Once properly set, wings may be trimmed rapidly, care being taken to apply the same amount of pressure each time with the blade. For rush jobs a separate trimmer should be available for each wing so as not to lose the time required in making the setting for different wings on the same trimmer. With eight trimmers available, all may be set simultaneously and all trimming for wing prints of the same camera accomplished. Resetting will then be necessary only when two or more cameras are used on the same job. Modified trimmers with refinements to permit faster operation are used by some organizations. (See fig. 28 ①.) An alinement templet and trimming data must be provided for each camera being used.

46. Mounting.—For mounting the composites it is preferable to use a pressed wood or masonite board with one side smooth, although bristol board will do. The boards to be used should be inscribed and



① Wing print trimmer ready for cut.

FIGURE 28.



② Modified trimmer with slow motion control, gradient, and magnifying glasses installed.

FIGURE 28—Continued.

lettered in accordance with the alinement templet (see fig. 24) and painted with rubber cement. Any number of these may be prepared in advance, conforming to the number of composites of each camera to be mounted. The B prints having been previously trimmed are painted with rubber cement on the reverse side and allowed to dry. After drying, and using a clean sheet of paper as an aid to keep the print from sticking to the mounting board except where desired, the B print is placed in position so that its collimating marks match the

inscribed marks on the mounting board. The wing prints are similarly mounted. The radial edges are trimmed by cutting with a razor blade through both overlapping wings and removing the trimmed off strips. In this operation it is desirable to use a clean strip of paper or acetate to keep those portions of the prints to be removed later from sticking to the mounting board. To the mounting board are then added the composite number and an arrow indicating approximate north. Each composite is then inspected for defects in mounting and corrected or accepted. Approximately 50 of such composites can be mounted by a crew of 30 men in an 8-hour day. (See fig. 23.)

SECTION V

PRICKING POINTS

47. General.—The operation of pricking points follows after the mounting of the composites and consists of pricking accurately on every composite the centers or substitute centers (within 1/16 inch of physical centers) of all surrounding composites, the field control points which fall on the composite, and all topographic points whose true horizontal position is needed to form a base for compilation. The points are pricked and transferred to all composites on which they appear, except that it is normally unnecessary to work on any composite outside of the area bounded by the principal points (centers) of adjacent composites. For the slotted templet or radial line plots it may be desirable to start with a selected set of pricked points which will include all principal points or substitute principal points, all field control picture points, and a limited number of selected points such that the total number of points will be at least 26 per composite. Additional points may be added while the radial line plots or slotted templet plots are being made.

48. Selection of topographic points.—The topographic points to be selected to a density of approximately one per square inch should be so selected as to be of greatest value to the compiler where possible. A compiler desires a dense net work of true positions so as to limit the possibility of making errors in his adjustments between these true positions. Long, flat stretches have no displacement and therefore need few true positions. For example, a long, straight,

level road without hills or dips requires only one true position at each end. On the other hand, every hilltop will be displaced and the compiler would like to have the true position of each one. This is not practically possible, but an effort should be made to select such points as may be considered tactically important. Important road junctions, stream crossings, stream junctions, important hilltops, and other features which may be of particular importance as potential artillery targets should be selected as points to be pricked. The selection and transfer of these points is a laborious process. The care with which it is done will be reflected in all later phases of the map making by the steorocomparagraph method.

49. Pricking and transferring topographic points and field control picture points.—Picture centers which have been marked in the mounting process may be transferred to all composites on which they appear. If they happen to fall in a spot which makes it impossible to transfer accurately, a more readily identifiable point may be selected within a radius of 1/16 inch from the picture center. All pricking of points, transfer of points, and selection of points should be done under a stereoscope. (See fig. 29.) Although some of the selected points may be transferred from composite to composite without the aid of a stereoscope, a majority will require stereoscopic aid both in selection and transfer. The use of the stereoscope for all transfers will be found most efficient, and little difficulty should be encountered, except in areas far out in the wings where the relief is high, if the composite centers are kept carefully alined with the axis of the stereoscope. The stereoscopic model may be viewed from two positions 180° apart. That position should be used which places shadows, if any, in proper relationship with the source of light. As the principal points are being mutually transferred to all composites, they should be numbered to correspond to the composite number and circled with blue ink (a pure blue which is not photographic). When this is done, field control picture points may be transferred to the composites with stereoscopic aid, circled and identified to include elevation, also with nonphotographic blue ink. This limited number of points may be transferred to all composites on which they appear without great difficulty, using any number of men, because each point bears an identification mark of some kind. It will normally be desirable to prick an additional series of selected topographic points so placed as to fall about halfway between the principal points appearing on each composite and the composite's own principal point. (See fig. 37①. These points should be marked and should insure a sufficient distribution of points to permit the running of a radial line

or slotted templet plot. The radial line or slotted templet plot may be accomplished at this stage, interrupting the completion of the point pricking operation or being coordinated with it. For the slotted

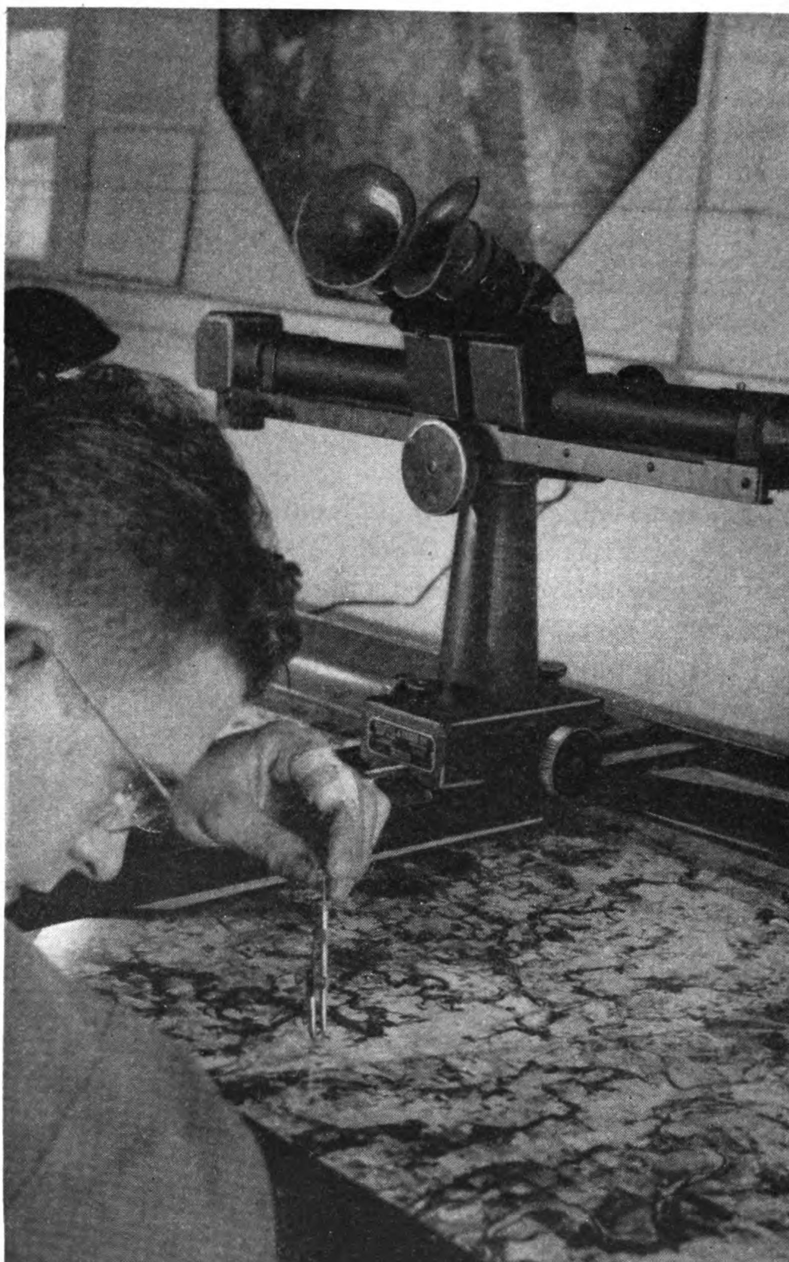


FIGURE 29.—Point pricker selecting, pricking, and transferring topographic points between composites under prismatic stereoscope—here shown circling a pricked point.

templet plot a short interruption will be involved as explained in paragraph 53 and depending upon the number of draftsmen available. The completion of the point pricking, which involves the selection of

points such as will provide a density of one per square inch approximately, is a time consuming and laborious operation with much depending on the skill used in organizing the work. With speed at a premium, it is desirable to put as many men to work as possible, and quite a few can be used if care is taken to assign specific tasks to each man so as to avoid conflicts caused when two or more men prick points in the same area on different composites. Two men unwittingly making selections of topographic points in the same area will not select the same points, and the resulting transfers to the other composites by still other men will result in a tangle of points most difficult to unscramble. Time cannot, as a rule, be spared to mark each point, but identification will depend on the position of the points which are marked (principal points, control points, and selected secondary points) and the pattern of the balance of the points. The unraveling of a tangle takes more time than would be consumed in doing the job carefully the first time, because the detection of the faulty pricking may not occur until other important steps have been taken in making the map, and the elimination of a point involves going back through all composites on which the point appears, erasing or crossing out the faulty point, and substituting a correct one. It will pay, in the long run, to take as much time as is necessary to plan the work, even to the point of outlining task assignments, so that there will be little danger of such confusion resulting from overlapping. The points selected should all be marked with nonphotographic blue ink.

Section VI

RADIAL LINE PLOTS

50. General.—Based upon the knowledge that with specification photography and for all practical purposes the photographic displacement of points is along rays through the points radiating from the photograph's center, a radial line plot may be made to determine the amount of this displacement away from or toward the center. This plot may be made in any of three ways at least and requires the use of overlapping photographs.

51. Radial line plotting.—A radial line plot may be accomplished by using continuous strips of a transparent medium long

enough to cover a line of flight and wide enough to cover one or more lines of flight as they appear on the projection. A sheet of acetate with one grained surface will answer the purpose. By placing the sheet to be used for the radial line plot on the projection board so as to cover the area desired, field control points may be transferred thereto by pricking and marking for identification. In the meantime on the composites themselves fine rays should be drawn, preferably with red ink and a crow quill pen, through each of the points to be used, extending about 1 inch beyond the points and 2 inches toward the composite center, these rays being drawn so as to radiate from the composite center. The acetate sheet may then be oriented over the first composite in a flight so that the plotted control points appearing thereon fall on the rays drawn through the corresponding points on the composite. With this orientation complete, rays are drawn on the acetate to conform to the rays on the composite. After this has been accomplished the composite is removed and the next overlapping composite is substituted. Orientation over this second composite is accomplished in the same manner as for the first, and rays are again drawn to conform to the rays appearing on the second composite. For points which appear in common on both composites there will now be two intersecting rays on the acetate, and the intersection will represent the true geographic position of the point to which the rays are drawn. As many rays may be drawn as there are composites which have a point in common, but three rays which intersect in the same point should be sufficient to establish the true position of a point. This radial line plot is continued as far as necessary using additional control encountered as a means of checking accuracy or making adjustments. An adjacent line of flight may be run on the same sheet and adjustments made to secure a proper tie between the flights. This constitutes a radial line plot, and the positions of intersections which represent the true positions of the picture points may be transferred to a compilation sheet and used as a basis for compiling a map to true horizontal scale and positions. The method is slow and its accuracy is dependent to a large extent on the accuracy and quality of the drafting. When a mistake is made or a doubt arises as to any intersection, it is necessary to go back to each composite involved to determine the source of the error. Orientation must in each case be painstakingly accurate, and only one or two men at the most can work on a single plot. It is possible and preferable to run the radial line plot first to establish a secondary horizontal control net consisting of principal points, substitute principal points, field control points, and selected secondary points. This will provide a horizontal control net of moderate density

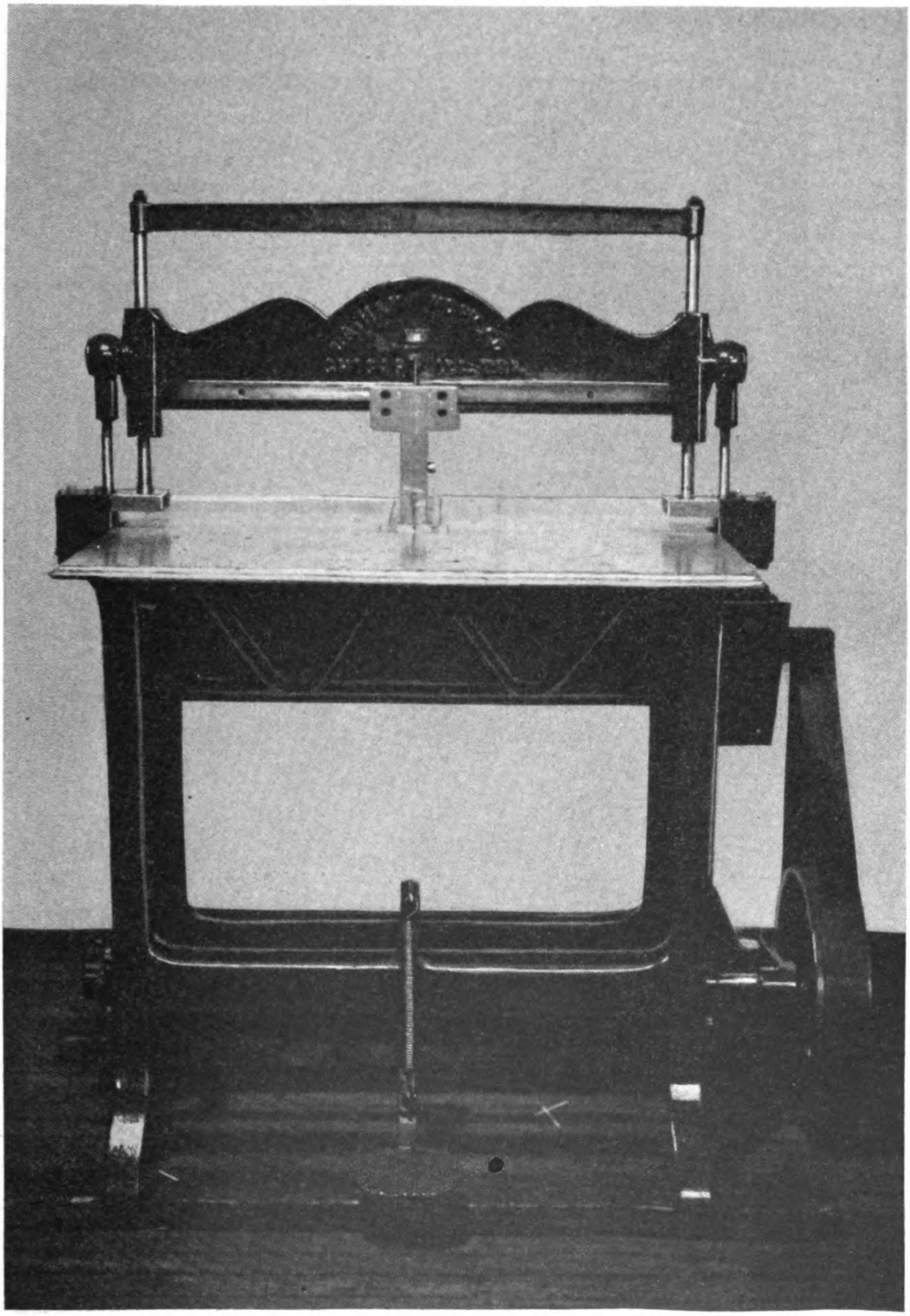


FIGURE 30.—Slot cutter for slotted templets for multiple-lens photography.

on which all necessary adjustments may be made. The density may then be increased to include all of the pricked topographic points. (See par. 78, TM 5-230.)

FIGURE 31.—Slot cutter for slotted templets for single-lens photography.

52. Radial line plot from individual templets.—A radial line plot may be expedited by using individual templets. In this case a number of templets of a transparent medium, such as cellulose acetate,

are prepared each of a size sufficient to cover a composite. One templet is placed over each composite and rays are drawn on it radiating from the composite center similar to the rays drawn for the radial line plot, one for each point to be used, the principal ones identified by marking. No rays need be drawn on the composites themselves. After a templet has been prepared for each composite they are laid down on the projection and oriented by having the control points fall on their corresponding rays. Templets having no control points are so placed as to cause rays thereon to form perfect intersections with

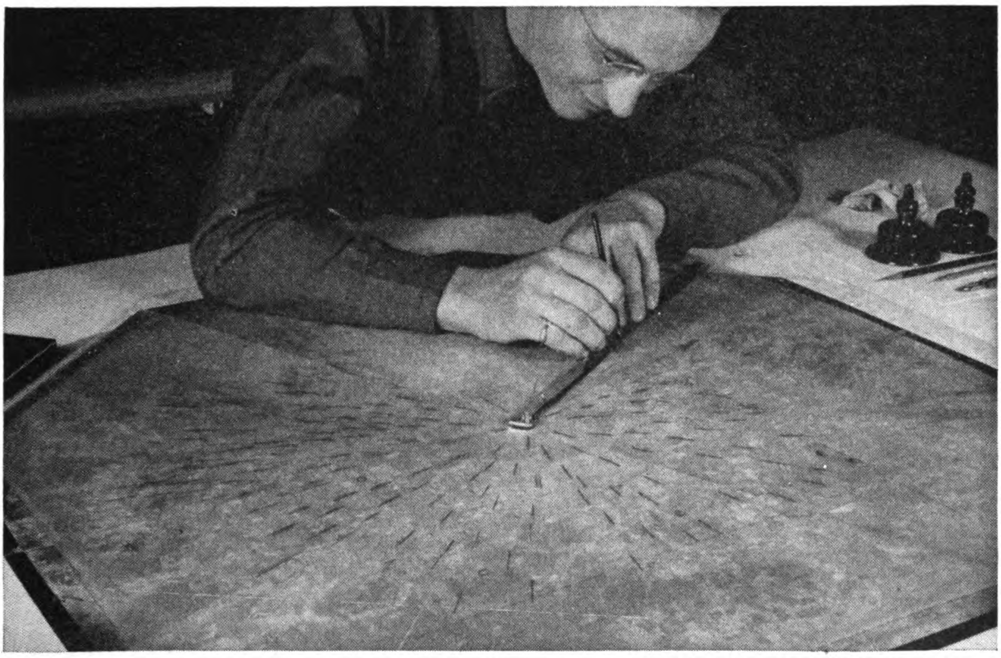


FIGURE 32.—Drawing rays to topographic points to be used in conjunction with the slotted templet method of radial line plotting.

corresponding rays on other templets. Each templet, except those fixed to control, is free to be moved around until a best possible solution has been determined, and the resulting intersections may be transferred to the projection by pricking through to the projection. The advantages in this method are that all available rays to points, rather than only three, may be used without greatly increasing the work, and faulty ones may be eliminated without attempting to determine the reasons for the fault; many draftsmen may be used in preparing the templets simultaneously, several men may be used in making the laydown, and adjustments may be made by shifting the templets at random without redrafting. (See par. 79*a*, *b*, and *c*, TM 5-230.)

53. Slotted templet.—*a*. Still a third method of making a radial line plot is by means of the slotted templet. This consists of substi-

tuting for the rays in the method described in paragraph 52 slots precisely cut (figs. 30 and 31) to be radial to the center and a center hole to replace the pricked center. Studs which snugly fit the slots are used to form a rigid frame work with the slotted acetate sheets. These studs are provided with holes through their centers so that the center of each stud may be located on the projection. This is a mechanical means of forcing the slots to assume accurate intersecting positions. In preparing the slotted templets, the procedure is similar to the preparation of radial templets except that rays need not be drawn. Any number of draftsmen may be used, up to the number of templets involved.

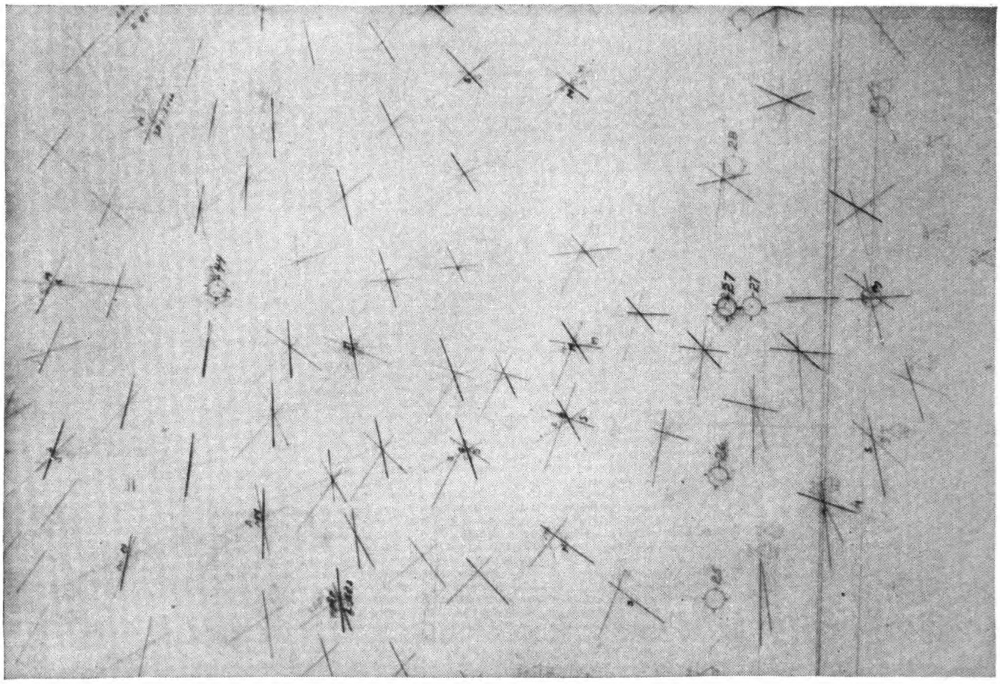


FIGURE 33.—Portion of lay-down of rayed transparent templets to determine true positions of topographic points as used in conjunction with slotted templet extension previously accomplished. There are shown four templets in position, so that some rays and figures must show through one or more thicknesses of acetate.

A templet is prepared by transferring to the acetate sheet the positions of the center and all points to be slotted, and marking same with a pin prick and identification. The center is punched out with a special punch, and this is used as a hub from which a mechanical slotter cuts the slots through each pricked point. On the projection, studs are fixed at each control point. The templets are then laid down so that the control studs fall in their corresponding slots. Additional loose studs are inserted into other slots and as the templets are laid these studs are moved to the point where corresponding slots cross each other. In this way templets are forced to assume a correct relative

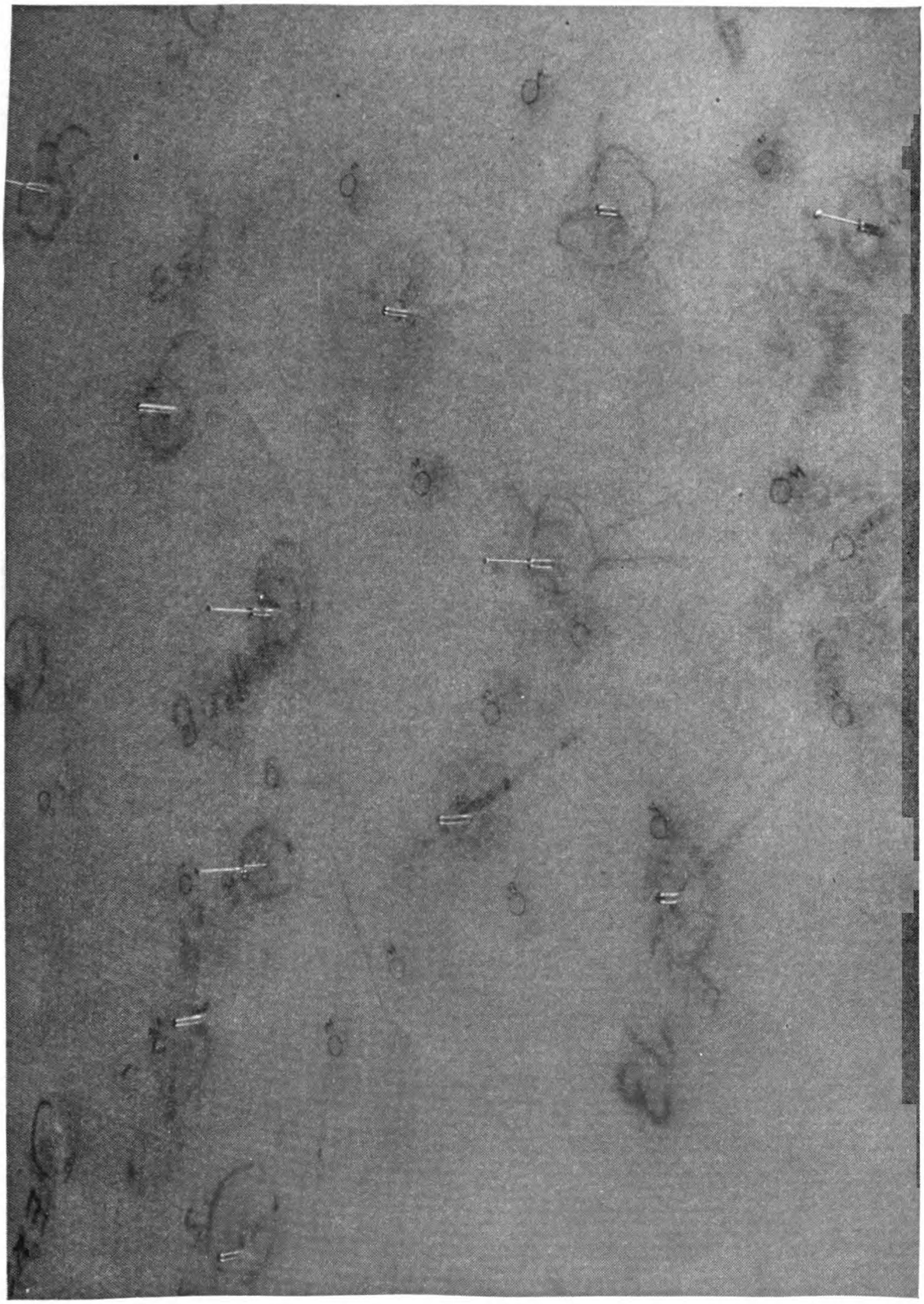


FIGURE 34.—Close-up view of portion of slotted templet lay-down with cellulose acetate templets.

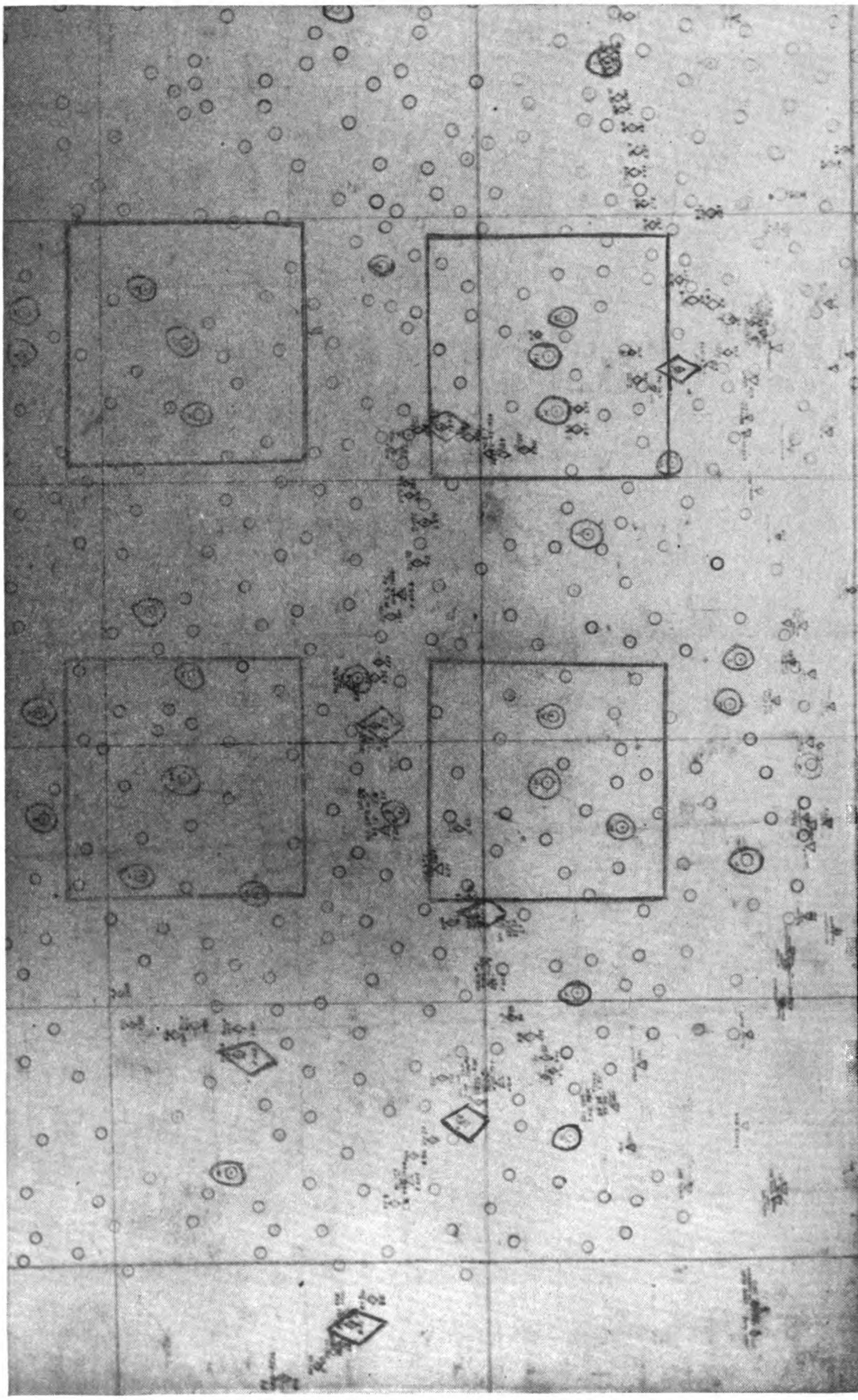


FIGURE 35.—Portion of projection board showing result of radial line plot.

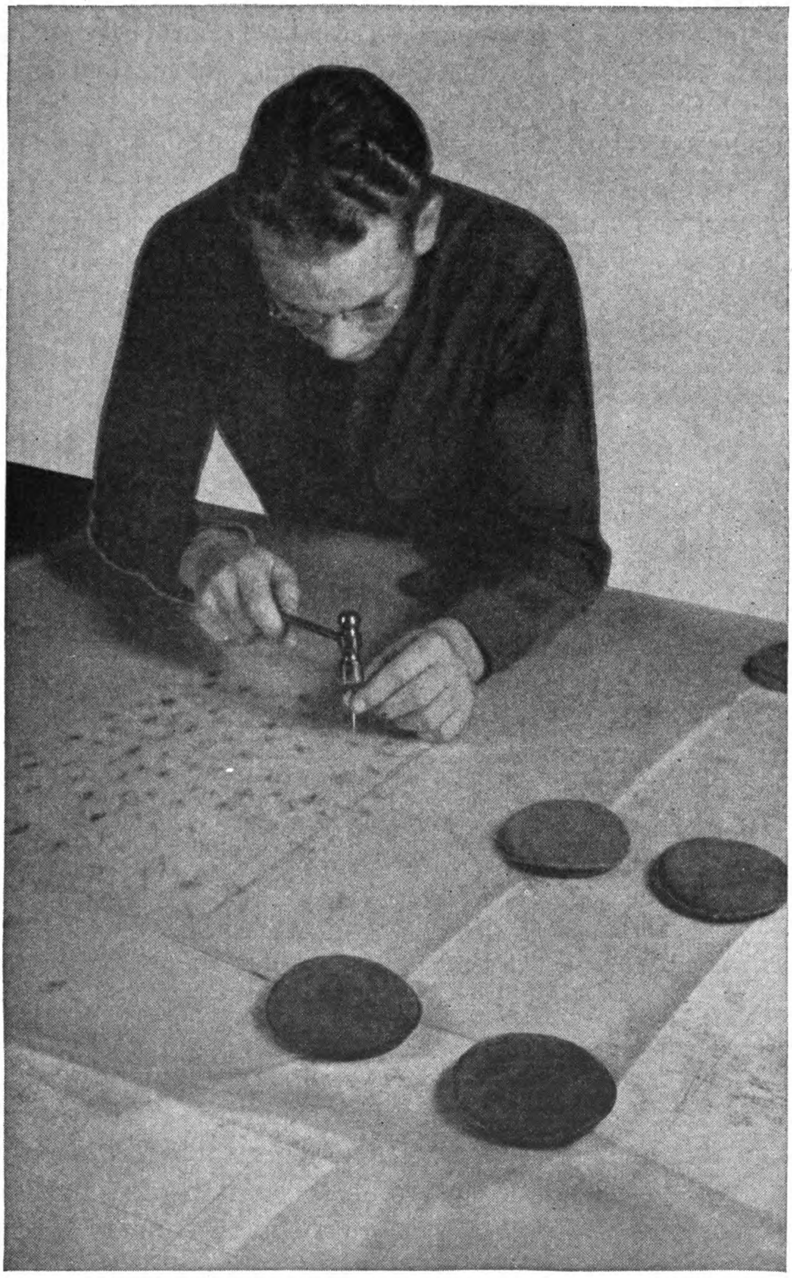
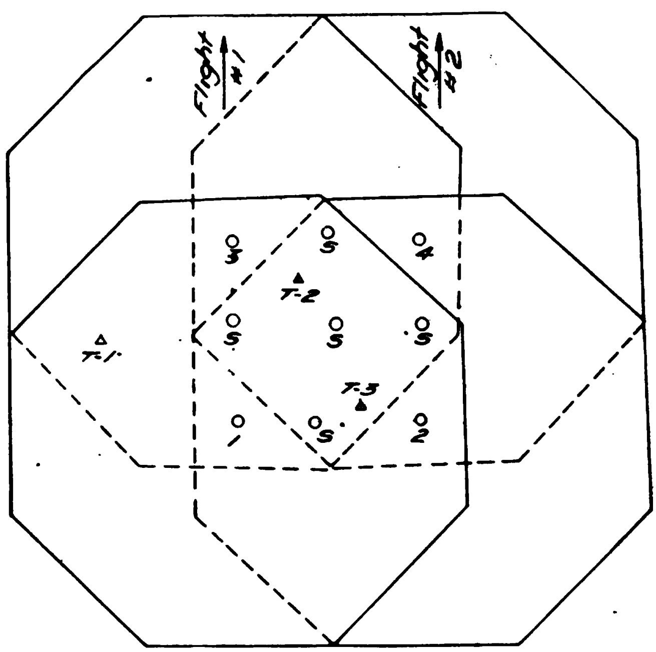


FIGURE 36.—Pricking through templets at ray intersections to mark these locations on projection.

position, and once any portion of the lay-down is fixed as by control points the balance must conform. (See figs. 34, 37①, and 38.) Faulty slots may be eliminated and even entire templets may be thrown out without seriously affecting the accuracy of the result. The lay-down may be repeated as often as desired until a satisfactory mean result is obtained, whereupon the intersections may be marked by driving pins through the center holes of all studs.

b. The slotted templets may best be used for the purpose of establishing a secondary horizontal control net consisting of the true positions of principal points, field control, and selected secondary points, to provide a density of about twenty-six points per templet. With this net

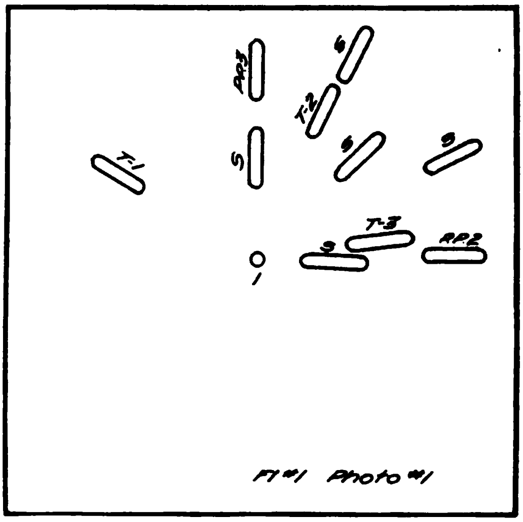


① Group of four composites showing principal points, field control, and secondary points pricked on photos for slotted templet plot.

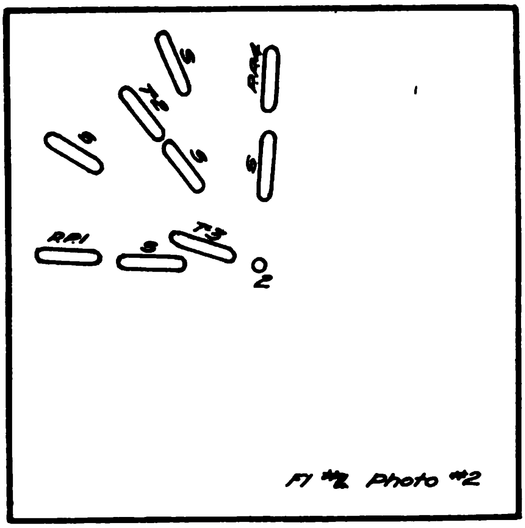
FIGURE 37.—Schematic diagrams.

available the true positions of other topographic points may be determined to the desired density by using a separate set of unslotted templets. The secondary horizontal control net established is extracted to the templets and is then used as a guide as to the displacements of other points nearby on the composites, so that short rays may be drawn on the separate templets, one for each topographic point desired, and in approximately the correct position to form intersections with other rays to the same point. (See fig. 32.) These templets may then be reoriented on the projection to fit the secondary control net (fig. 33) and the various ray intersections transferred to the projection by pricking through (fig. 36). The completed projection (fig. 35) will

have a network of points of the desired density and is available for use by compilers who may extract such data as they require directly from the projection and begin their compilation work. For slotted templets, it is desirable to have a fairly rigid material, transparent, if possible, such as cellulose acetate about 0.012 inch thick, but bristol board or steel shim stock or similar material may be used. The slotted



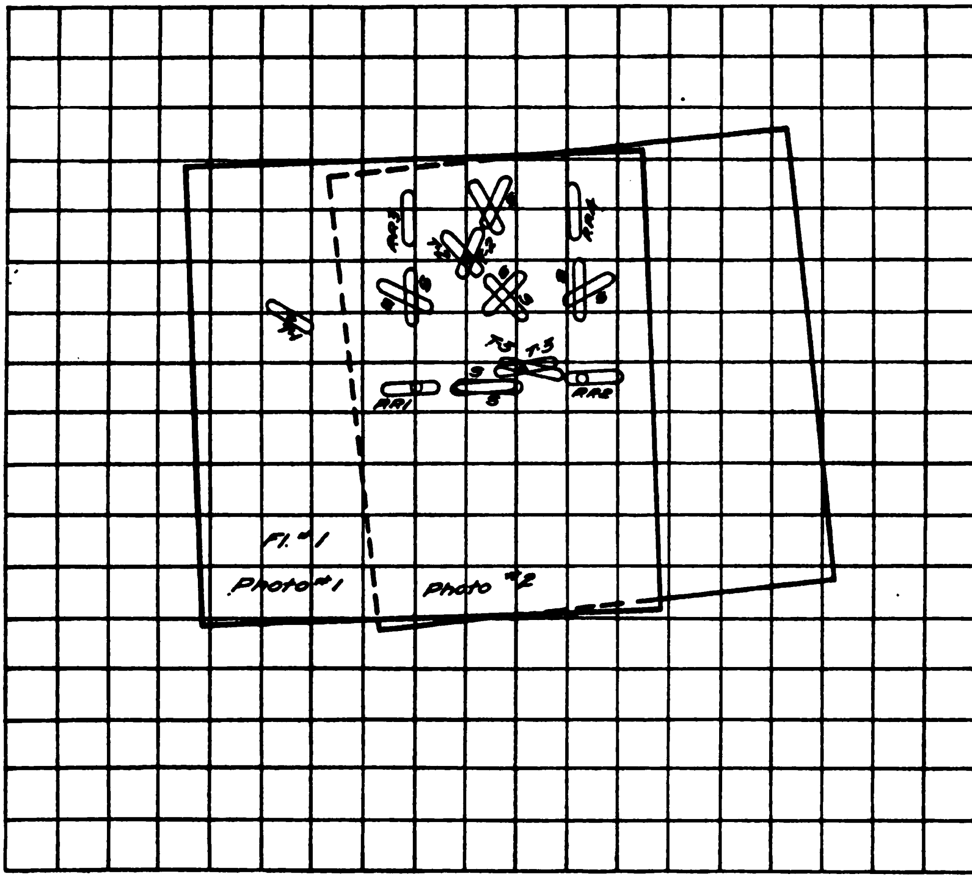
Ⓖ Slotted templet for composite No. 1.



Ⓗ Slotted templet for composite No. 2.

FIGURE 37.—Schematic diagrams—Continued.

templet has a great advantage in speed, particularly for large areas, and possibly in these cases some advantage in accuracy. (See par. 79*d* to *i*, incl., TM 5-230.)



④ Slotted templets for composite Nos. 1 and 2 oriented on projection board. Intersections of slots give true positions of slotted points. Special studs with center hole in shaft ride in slots to fix exact intersection. Studs for control points are fixed in position. Addition of more templets increases the number of slots intersecting at each stud and permits a more positive determination of the proper point of intersection.

FIGURE 37.—Schematic diagrams—Continued.

SECTION VII

ADDITIONAL PROCEDURES

Paragraph

54. Preparation of multiplex work sheets.—Multiplex work sheets may be prepared as described in paragraph 23. This may be

done as a rule to best advantage after the slotted templet plot has been made, although it may be started after the field control only has been plotted on the projection, and tentative extensions of vertical control begun without the aid of the horizontal control later established by the slotted templet plot. The horizontal control established by any radial line method and required for compilation purposes may be added to the work sheets as soon as it becomes available and should be of assistance to the multiplex operators where long extensions are involved.

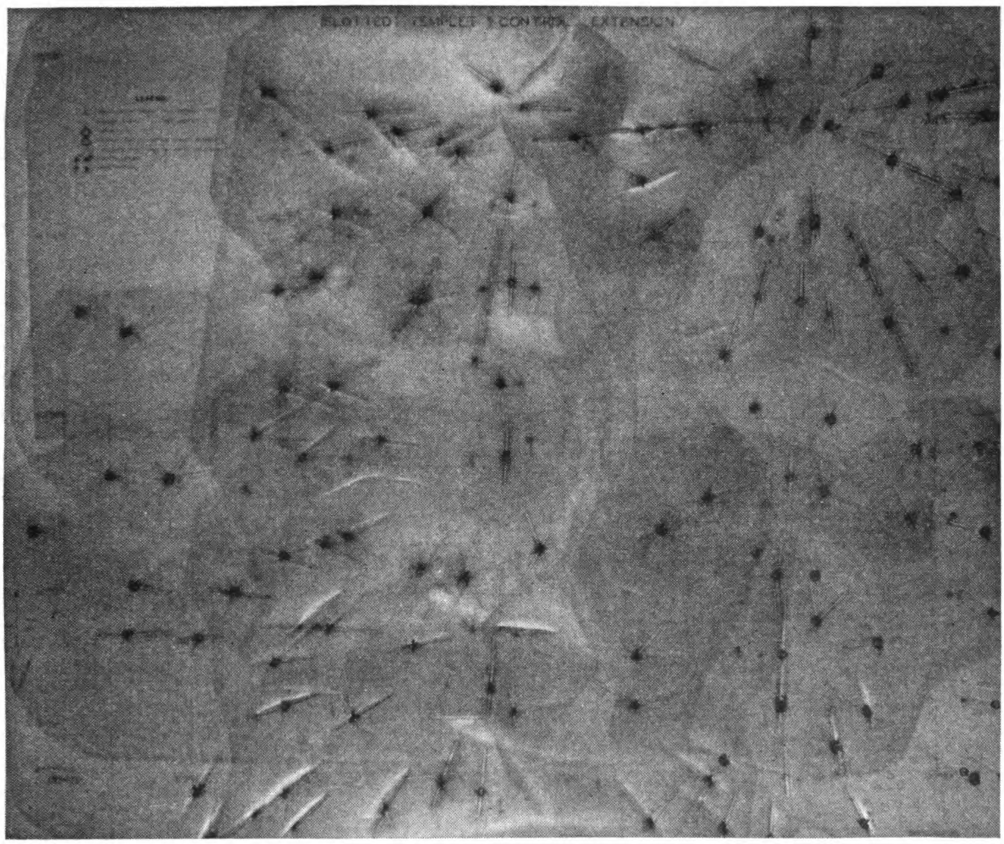


FIGURE 38.—Vertical view of slotted templet lay-down reduced to one-tenth original size. Area covered represents approximately three 15-minute quadrangles or almost 700 square miles. Cellulose acetate is the templet material and original photographs were tandem T-3A composites at a scale of 1/40,000. The bases of the templet studs can be seen through as many as six layers of templets.

55. Printing diapositives.—Diapositives for use with the multiplex may be printed at any time after the receipt of the negatives. Only one set will be required, although two sets of the diapositives of the B prints may be desirable if there is an opportunity to run duplicate control extensions simultaneously for cross-checking purposes. The detailed process involved in printing the diapositives is explained in the Multiplex Operator's Manual. (See par. 17.)

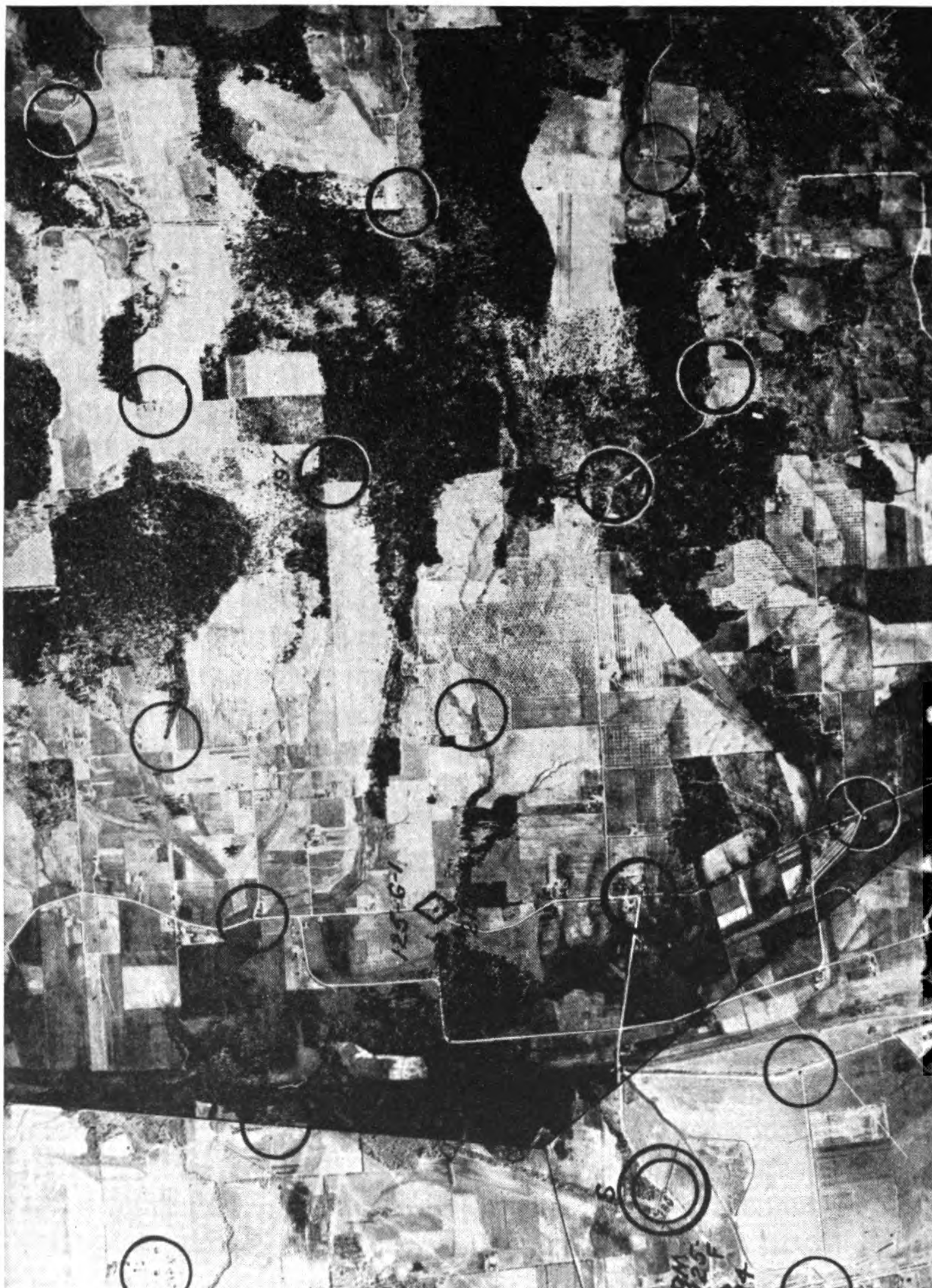
56. Compilation of planimetry.—*a.* The process of compiling planimetry, which is all the map detail other than hypsography, may be begun as soon as the radial line plot is complete and the true horizontal positions of a network of points of density of about one per square inch have been determined. The true positions of the points required may be on the medium on which the radial line plot was made or on the projection, depending upon the method used in making the radial line plot. In normal cases for large projects the data will be assembled on the projection. The next step is a transfer of the information to the compilation sheet by direct tracing. The compilation sheet is normally a cellulose acetate sheet with one grained surface and about 0.00825 inch thick. It may be of a size sufficient to cover an entire 15-minute quadrangle, or it may be for a smaller area depending upon the number of draftsmen it is desired to put to work at the same time. If reproduction is to be at a larger scale than the compilation, for example at 1/20,000, it will be desirable to have the compilation sheets of such a size as to correspond to a complete sheet of the reproduced map, and this will be dependent on the size of sheet which can be printed in the presses available in the field. (See par. 28, FM 30-20, and TM 5-245.) The process of compilation may be accomplished in at least two ways, one of which requires no special equipment. In the latter method each compiler takes his compilation sheet and extracts by direct copy from the projection all of the information as to the true positions of the selected topographic points and field control pertaining to his area. These points should be identified by pricked points with circles for topographic points inked with nonphotographic blue ink or a conventional sign of the proper type to indicate control points. A composite is next selected which has the area involved closest to its center. On this composite the topographic points for which true horizontal positions are now available likewise appear as pricked points circled in blue ink. The job of the compiler is to extract all useful information from the composite to his compilation sheet and in such a way that the topographic points will fit the positions shown on his compilation sheet. This involves correction of the photographic displacements resulting largely from relief or the change from a perspective projection to a true orthographic projection. The compiler may place one point on his compilation sheet over the corresponding point on the composite, keeping it properly oriented in azimuth, and extract all useful information from the composite in the immediate vicinity of that point. He may then move this compilation sheet until the next point is in coincidence with its corresponding point on the composite and repeat the operation. Adjustments must be made to provide a proper junc-

tion for the two plots. Another method is to move the compilation sheet gradually in the directions indicated by the displacements of the points on the composites and in such a way that as each marked point on the compilation sheet is reached it is in coincidence with the corresponding point on the composite. Major features such as roads may be compiled first, or all planimetric detail such as culture, hydrography, and woods may be compiled simultaneously. The result will be a planimetric map to a true orthographic projection, lacking only hypsography to make it a complete map suitable for all military purposes. (See fig. 39.) As topographic plots by stereocomparagraph operators become available they are compiled in the same way as for planimetry.

b. Another method which may be used in compilation requires the use of a projector which can project a portion of the photograph or composite to the compilation sheet, and which has provision for tip, tilt, enlargement, or reduction so that a group of points on the photograph may be made to coincide with the corresponding group of points on the compilation sheet. When this coincidence is effected, the area bounded by these points may be compiled directly by copying desired detail from the projected image. A planimetric map compiled as above may be issued to troops without topographic information other than field control elevations, or with such spot elevations as may have been by this time determined by the multiplex operators. Care should be exercised in compilation to use the sizes of conventional signs and weights of lines such that they will be properly represented at reproduction scale.

57. Vertical control extension.—While the compilation work is in progress, the vertical control may be extended with the multiplex equipment. Utilizing such horizontal control as may be available from the radial line plot and the field control, the multiplex operators may run extensions as described in the Multiplex Operators Manual (par. 24) for the purpose of establishing enough elevations on each stereoscopic pair to permit stereocomparagraph operators to complete the plotting of topography. In this operation, which may be carried on simultaneously by more than one crew working independently, it will be advantageous to set all projectors initially at the height corresponding to the flight height and to correct this height only as a last resort in making the absolute orientation. With horizontal control available and height of the projectors established, the swing, *bx*, *by*, and *bz* motions of the projectors are predetermined, and only the tip and tilt motions remain to be applied to secure satisfactory relative orientation of those projectors set up to extend the control beyond

starting control. The first projectors have been absolutely oriented over the starting control. Once the projectors for a flight line have

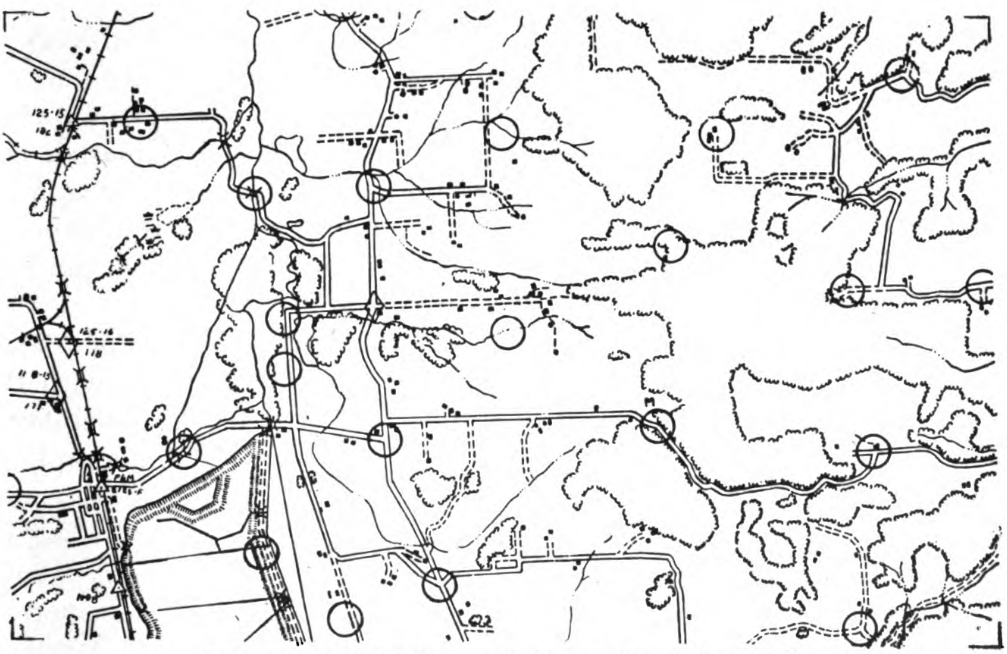


① Portion of aerial photograph with topographic points marked thereon.

FIGURE 39.

been established in positions which give acceptable results, there remains only the task of determining the elevations of a number of

points on each stereoscopic pair to be contoured by stereocomparagraph. For this purpose approximately six elevations will be sufficient if well distributed in the area of overlap. The elevations and positions of the points selected are transferred by the multiplex operators to the photographs to be used by the stereocomparagraph operators, the positions by pricking and marking, and the elevations by marking same on the back of at least one of the photographs. When this has been accomplished the photographs are delivered to the stere-comparagraph section which completes the topographic plotting of the B prints. Similar control must be made available for those wing prints which must be used to provide complete coverage.



② Planimetric detail compiled from above photograph.

FIGURE 39—Continued.

58. Establishing vertical control for wing prints.—Depending upon the spacing of the flights, one or both opposing wing strips may have to be used in plotting topography to obtain coverage of the area. If the gap between two flights is so small that it may be covered by the use of one series of wing prints, when using these wing prints only as far out as their collimating marks, then it will be necessary to establish the vertical control for the one series. If this cannot be done, then both complete series of opposing wing prints between two lines of B prints must be controlled. Control cannot be extended by the use of oblique projectors because of inherent inaccuracies of these instruments. However, by using them as individual pairs to

set up one model at a time based on established control, a satisfactory orientation may be made and additional spot elevations determined or the model may be completely plotted. To use the oblique projectors as indicated above, the elevations determined as a result of the work with the B prints of two adjacent flights are transferred to the pair of wing prints for which more control is desired. Elevations along two lines on the wing prints should be available, one line in the area which is common to the wing prints and their corresponding B prints, and one line along the nearest edge of the B prints of the adjacent line of flight. Although all of the elevations determined on the B prints of the adjacent line of flight may be transferred to these wing prints, generally speaking, only those which fall nearest to the inside edge will be useful. With such elevations available, it is possible to make a satisfactory orientation of a pair of oblique projectors and then to determine a sufficient number of additional elevations to provide complete control for stereocomparagraph plotting. The information is supplied to the stereocomparagraph section in the same manner as for B prints. Occasionally, when adjacent flights are very close together, wing prints may be contoured by using only that control which can be extracted from previously controlled B prints.

59. Contouring by stereocomparagraph.—With complete stereoscopic coverage of the area being mapped now available with B prints and wing prints supplied with vertical control by the multiplex, the stereocomparagraph may be used to complete the topographic plotting. This may be done in accordance with instructions contained in paragraphs 82 and 88, TM 5-230. (See figs. 40 and 41.) In order to permit the proper compilation of the resulting individual topographic plots, it is necessary to have transferred to the photographs used the network of field control points, principal points, secondary points, etc., which appear on the corresponding prints as mounted in the composites. These points are likewise transferred to the individual topographic plots so that they may be used as a guide by the compiler in compiling the plot to true horizontal position. It is to be understood that the topographic plotting with the stereocomparagraph will contain the normal photographic displacements which must be rectified in the same way as planimetric detail. In addition to marking on each plot the positions of all topographic points used as a basis for compilation, it is desirable to sketch in sufficient detail to aid in the orientation of each plot under the compilation sheet. It may also be desirable to note important cultural features which might otherwise be overlooked by the compiler. Since each stereoscopic pair is studied intently for several

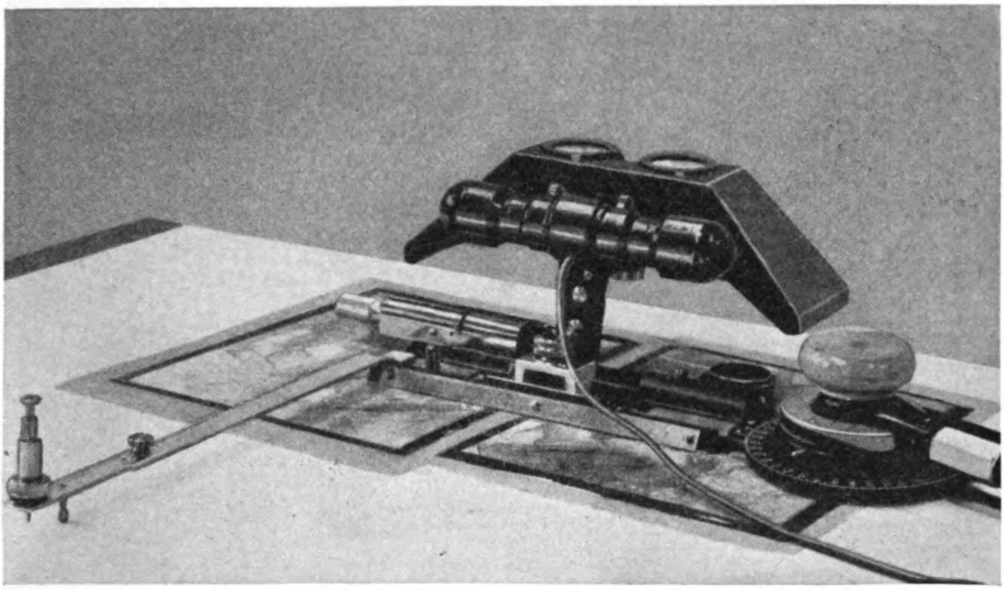


FIGURE 40.—Stereocomparagraph.

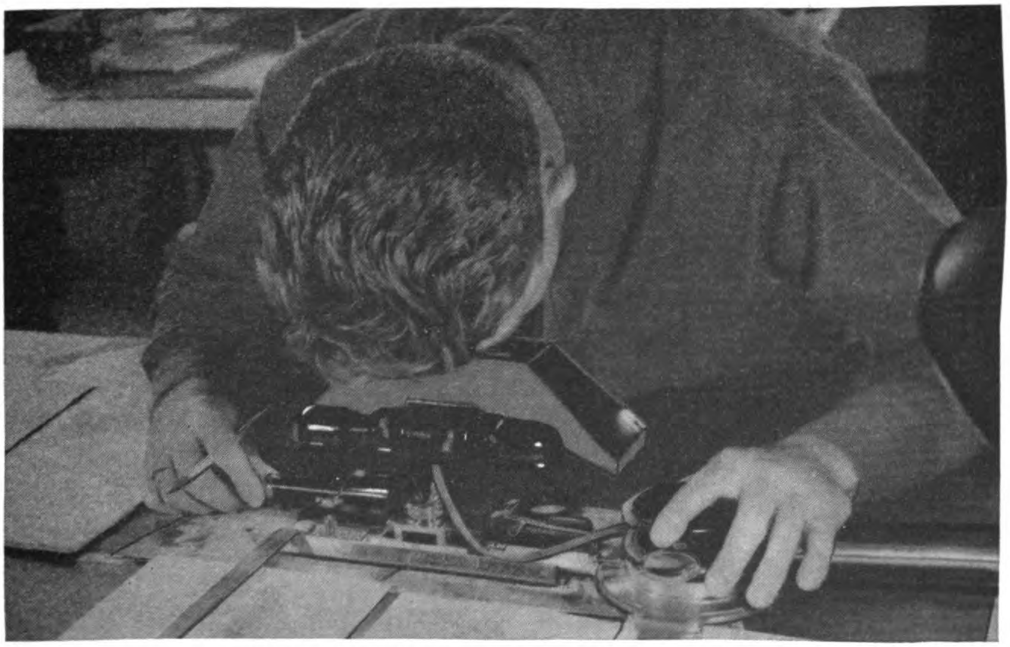
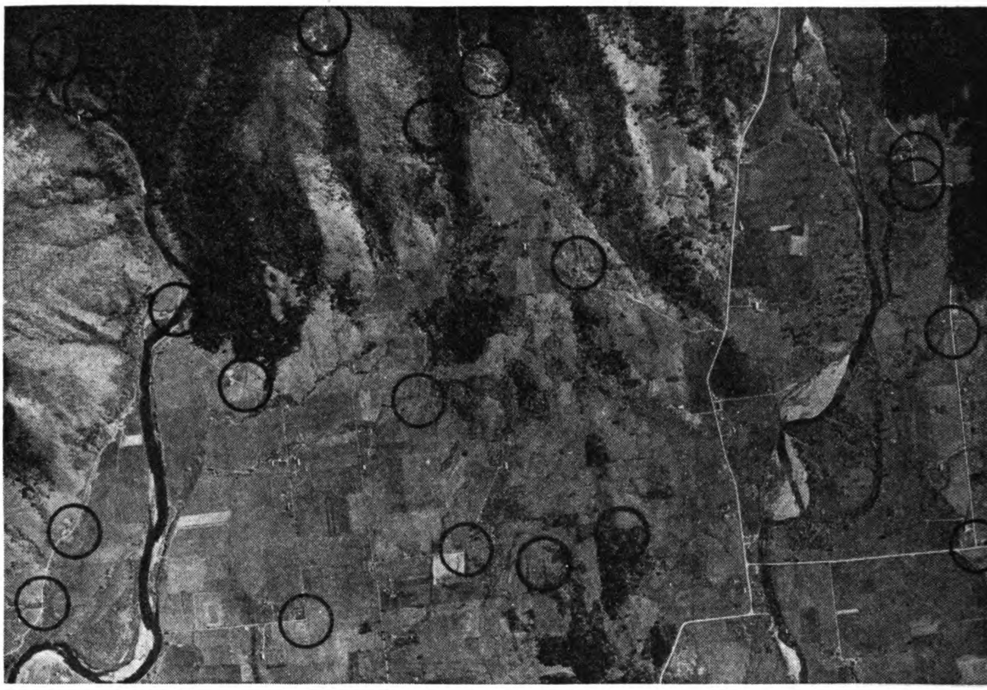
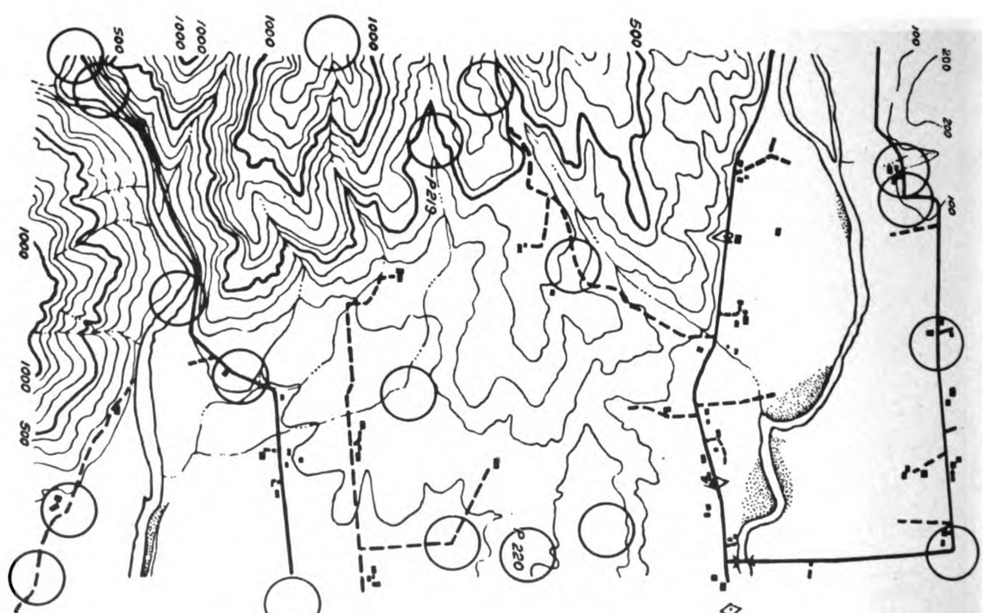


FIGURE 41.—Stereocomparagraph in operation.



①

FIGURE 42.—Portion of aerial photo and stereocomparagraph plot therefrom.



②

FIGURE 42.—Portion of aerial photo and stereocomparagraph plot therefrom.

hours during the plotting operation, there is an excellent opportunity to use this phase as an aid in the interpretation of the detail appearing in each photograph. If the attention of the compiler is called to the existence of important detail, he will be enabled to incorporate it into his compilation. The development of acuity of stereoscopic vision necessary for this work is a matter of several weeks of training men with good eyes and good control of their eyes.

60. Compilation of topography.—Individual topographic plots, representing the topography covered by one stereoscopic pair, and including the locations of all points used in the radial line plot as well as some planimetry, are the product of the stereocomparagraph

FIGURE 43.—Compilation sheet being completed.

section. When completed they are delivered to the drafting section for compilation. The compiler compiles each topographic plot in the same way as he does planimetry, by adjusting the topography so that the marked points fit the true positions as indicated on the compilation sheet. The top of a hill may have to be moved over a considerable distance and all contours of the same hill adjusted to fit this new position, using the stereocomparagraph plot as a guide to the conformation of this hill. A compiler should have a considerable amount of training in this type of work and should be familiar with the effect that photography has in the displacement of topography. The exercise of good judgment will be essential in many cases, but where there exists considerable doubt as to the prob-

able position of any topographic feature, time should be taken to determine its true position by pricking the point on at least three overlapping composites on which it appears and then executing a radial line plot for this one point directly on the compilation sheet, using surrounding established points for orientation. In drafting of contours, every fourth or fifth contour is intensified to improve the readability of the map, and it is efficient and desirable to compile these intensified contours first in a limited area and then to interpolate the intermediate contours while studying the stereocomparagraph plot. (See figs. 42 and 43.) (For more detailed instructions see sec. XX, TM 5-230.)

61. Blue line preparation.—When the compilation is complete, a negative thereof is made at the color separation scale and blue line drawings prepared as described in paragraph 28.

62. Color separation drawing.—Same as in paragraph 29.

63. Field check and edit.—Same as in paragraph 30. (See fig. 44.)

CHAPTER 5

MAP SUBSTITUTES

64. General.—The situation involved in a military operation may be such that a substitute of some kind may be desired before the topographic map produced as described above is ready for issue. Such a map substitute may be desired in the shortest possible time and photographs alone may serve the purpose, or some additional embellishments not requiring much time may be found desirable. (See secs. VIII, XIX, and XXII, TM 5-230.)

65. Uncontrolled mosaics.—*a*. If the reproduction of photographs as individual prints is undesirable because of the limited area each print covers, an uncontrolled mosaic may be prepared by assembling several photographs into single sheets simply by matching detail as closely as possible. Individual prints covering the area or size of sheet desired are assembled and trimmed along lines which permit the best matching of detail. A good practice is to cut lightly along the trim lines with a razor, feather the edge by tearing along the trim line, and then to finish the feathering by sandpapering to a fine edge. After the feathering, the portion of the print to be used may be mounted on a board with gum arabic in a thin solution. Saturation of the prints with the solution will permit minor stretching to secure better matching of detail if necessary. The uncontrolled mosaic is normally provided with an atlas grid, place names, and marginal data. The marginal data may be added by preparing a mask containing the necessary information and photographing the mosaic with the mask in position. The names and grid lines may be drawn in black or white on the mosaic itself or on the negative prepared for reproduction purposes. Uncontrolled mosaics will have all of the displacements of detail common to all photographs and will have no topographic information. They are not accurate as to scale and direction and can be used for general planning only where precision or topographic information is unnecessary. (See fig. 45.)

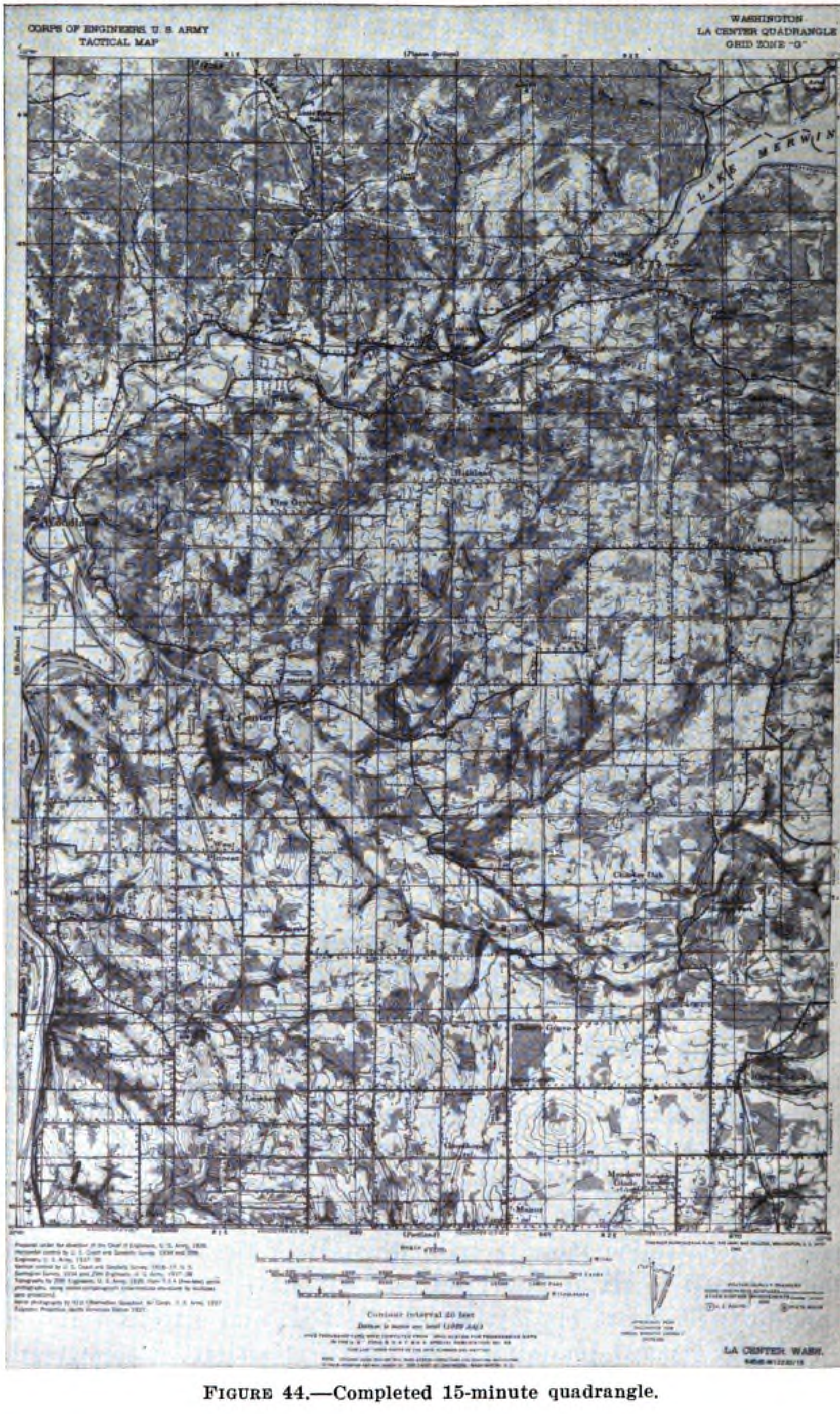


FIGURE 44.—Completed 15-minute quadrangle.

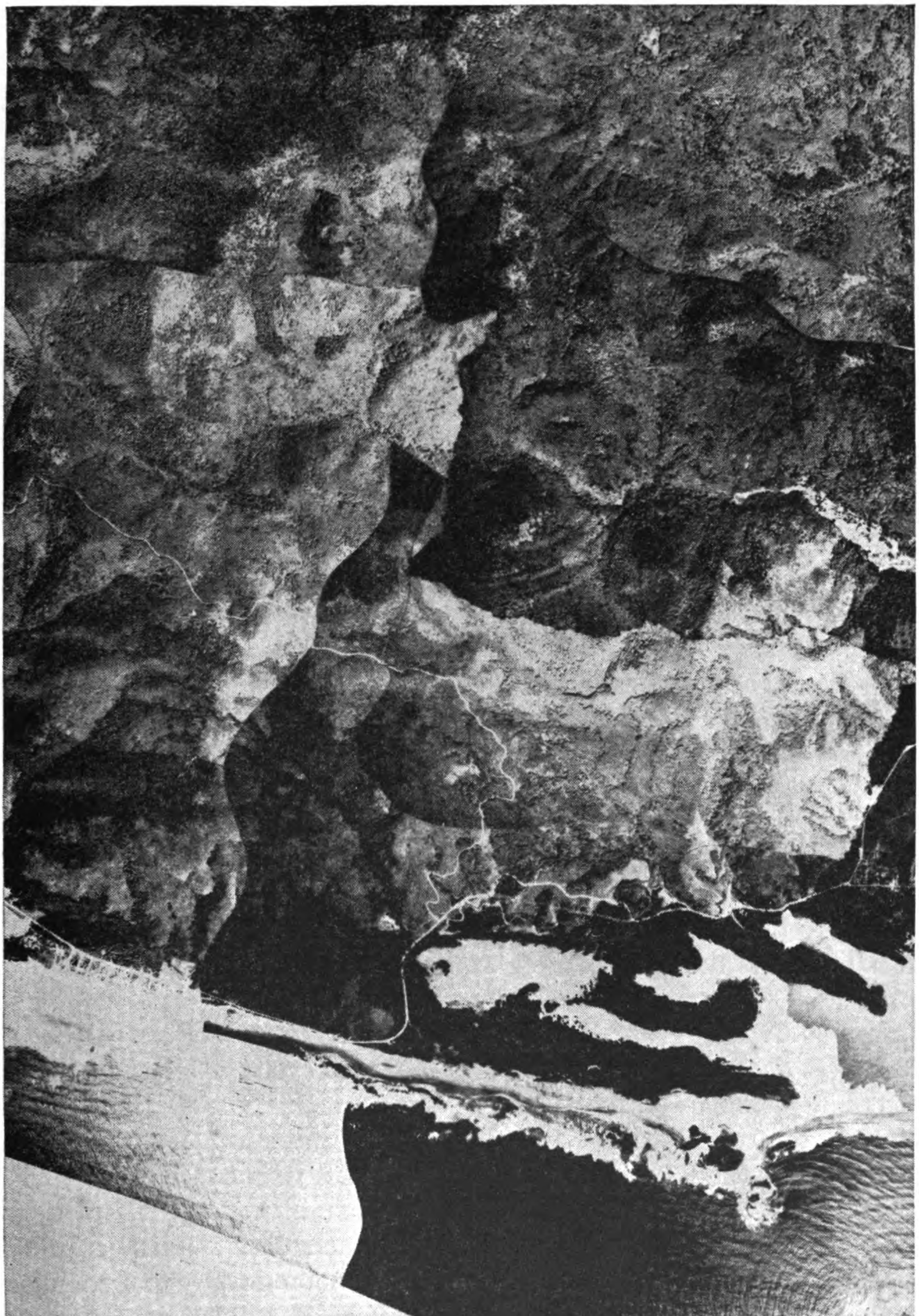


FIGURE 45.—Portion of uncontrolled mosaic.

b. A form of uncontrolled mosaic not to be overlooked is the mounted composite of a tandem T-3A camera. Such a composite at a scale of 1/40,000 covers an area of over 300 square miles. If a larger scale is desired, a central portion of the composite may be enlarged with good results. (See fig. 46.) If the coverage of a single composite is insufficient for the mosaic desired, it is preferable to use single lens photography and, when this is done, some advantages in the quality of the mosaic may be gained by using cameras of relatively long focal length. It may be desirable at times to mount a mosaic of a large area and to photograph it piecemeal with suitable masks for reproduction in sheets which can be handled in the presses available. In this case, care should be taken to insure that camera facilities available can be arranged to copy every portion of the mosaic.

66. Photomaps.—Photomaps are in reality map substitutes consisting of copies of individual photographs or mosaics prepared with grids, names, and marginal information so that they may be distributed widely and used in place of a map. Uncontrolled mosaics, controlled mosaics, contoured or uncontoured photos or mosaics properly provided with names, grids to permit orientation by coordinates, and marginal information similar to that found on a topographic map are classified as photomaps. A composite embellished in the same manner may be considered a photomap. Such photomaps may be readily prepared for issue. All except those based on controlled mosaics have the displacements inherent to all photography. This displacement is too large to permit the use of this type of map substitute for many purposes. As an example of the displacements which will be involved (these may be computed approximately if the elevations of the points are known), with photography at 10,000 feet with a 6-inch focal length camera giving a photo scale of 1/20,000, a point 500 feet high and 6 inches away from the photograph center will be displaced outward approximately 0.3 of an inch which corresponds to approximately 166 yards. For lower photography, higher elevations, or distances farther from the photograph center, the displacements on the photograph are proportionally larger.

67. Controlled mosaics.—The term "controlled mosaic" is as indefinite as the term "map" in that both will vary considerably with the amount of control used. The most highly controlled mosaics involve ratioing each print and in many cases each small portion of a print. This ratioing means bringing the photography to a common scale. Partially controlled mosaics may be assembled in the same way as uncontrolled mosaics, with the exception that at least one point on each photograph is made to fit its true geodetic position,

and normally it is desirable to locate the true position of each photo center. This may be done by making a radial line plot to determine the true positions of these points. This presupposes the availability

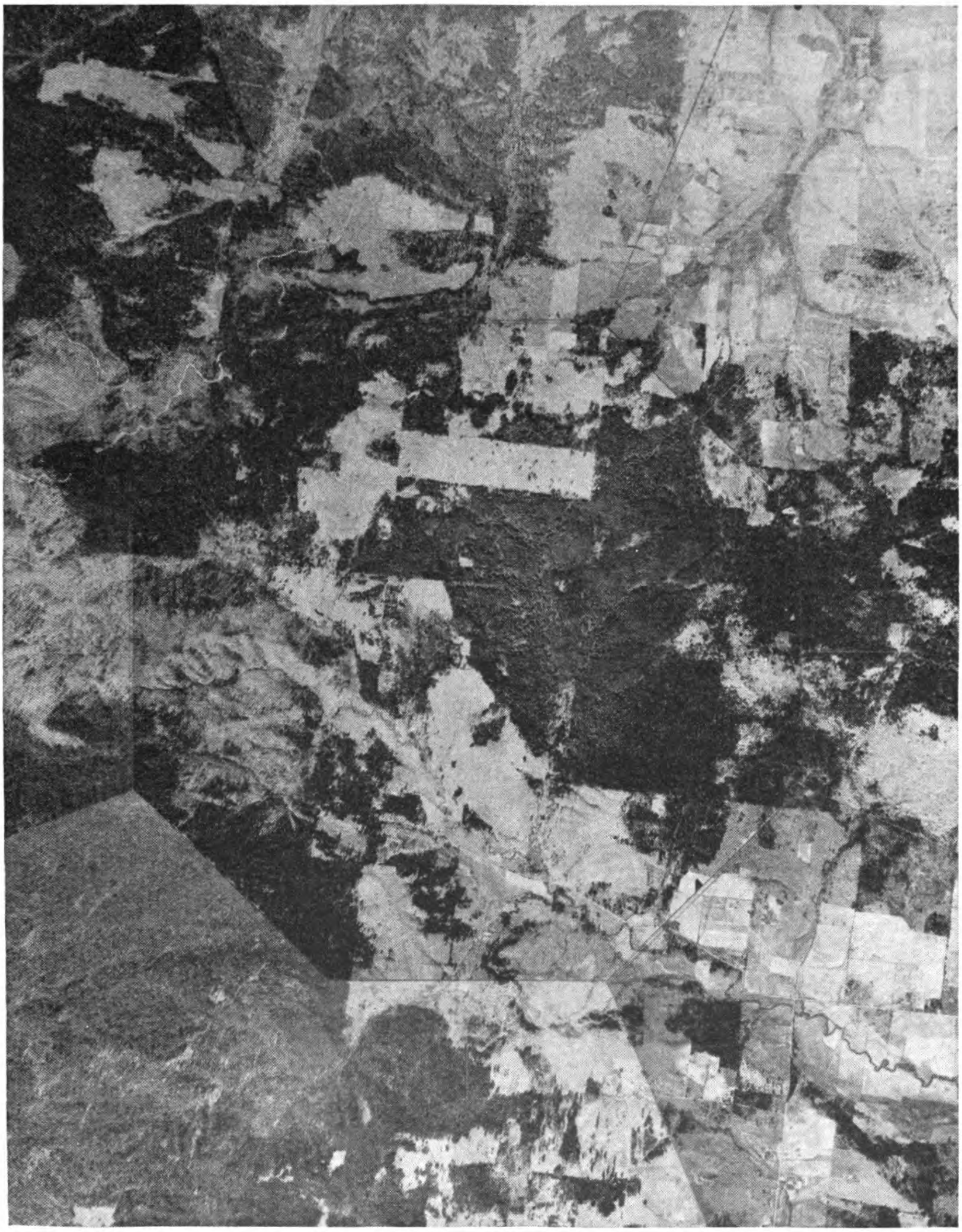


FIGURE 46.—Central portion of a composite, a form of uncontrolled mosaic.

of enough field control to start the radial line plot. The field control and the true positions of each photo center are plotted on the board on which the mosaic is to be mounted. Photos are then

trimmed, feathered, and mounted as for an uncontrolled mosaic, making the photo centers fall on their true positions and striving at

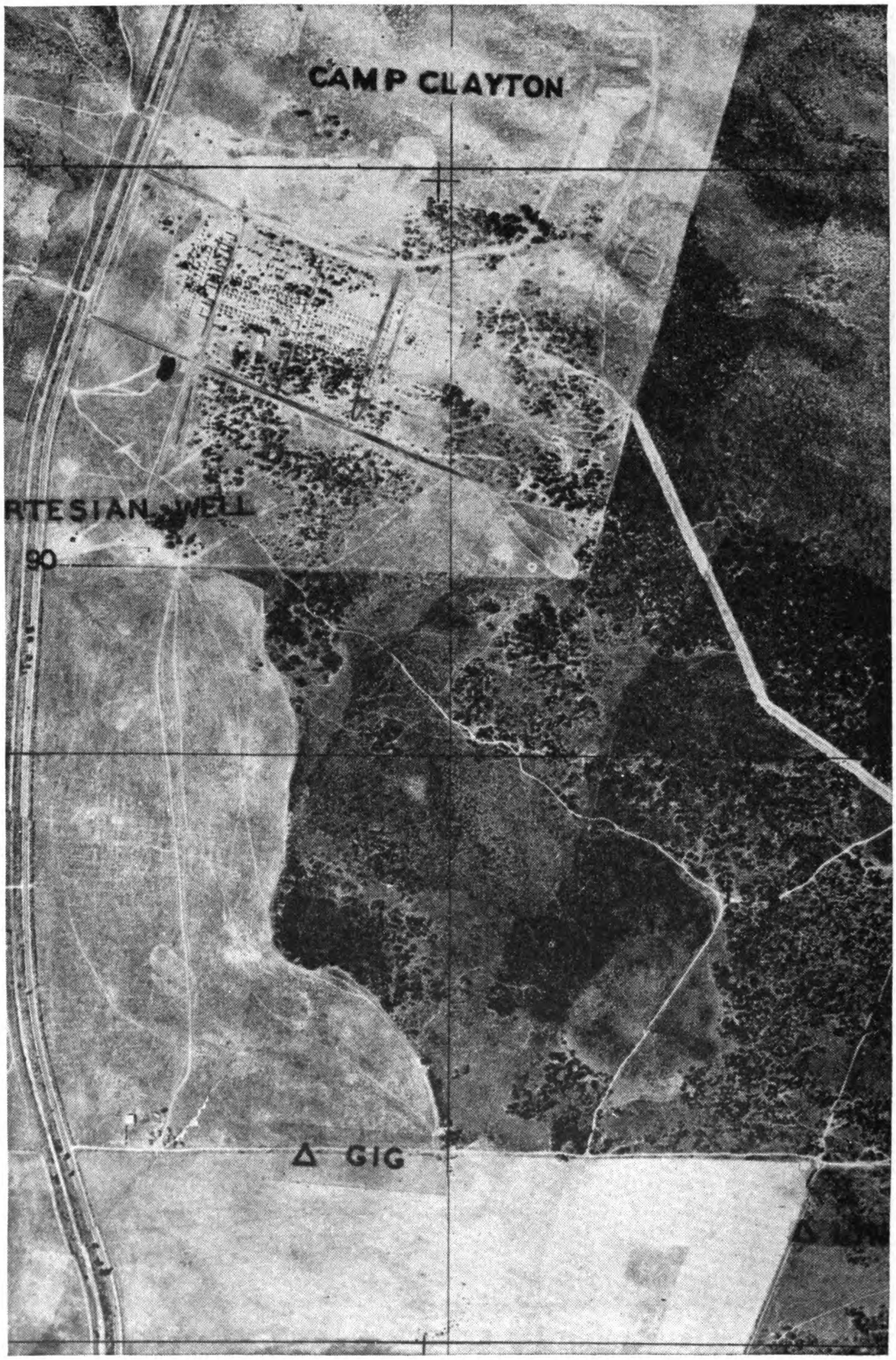


FIGURE 47.—Portion of controlled mosaic.

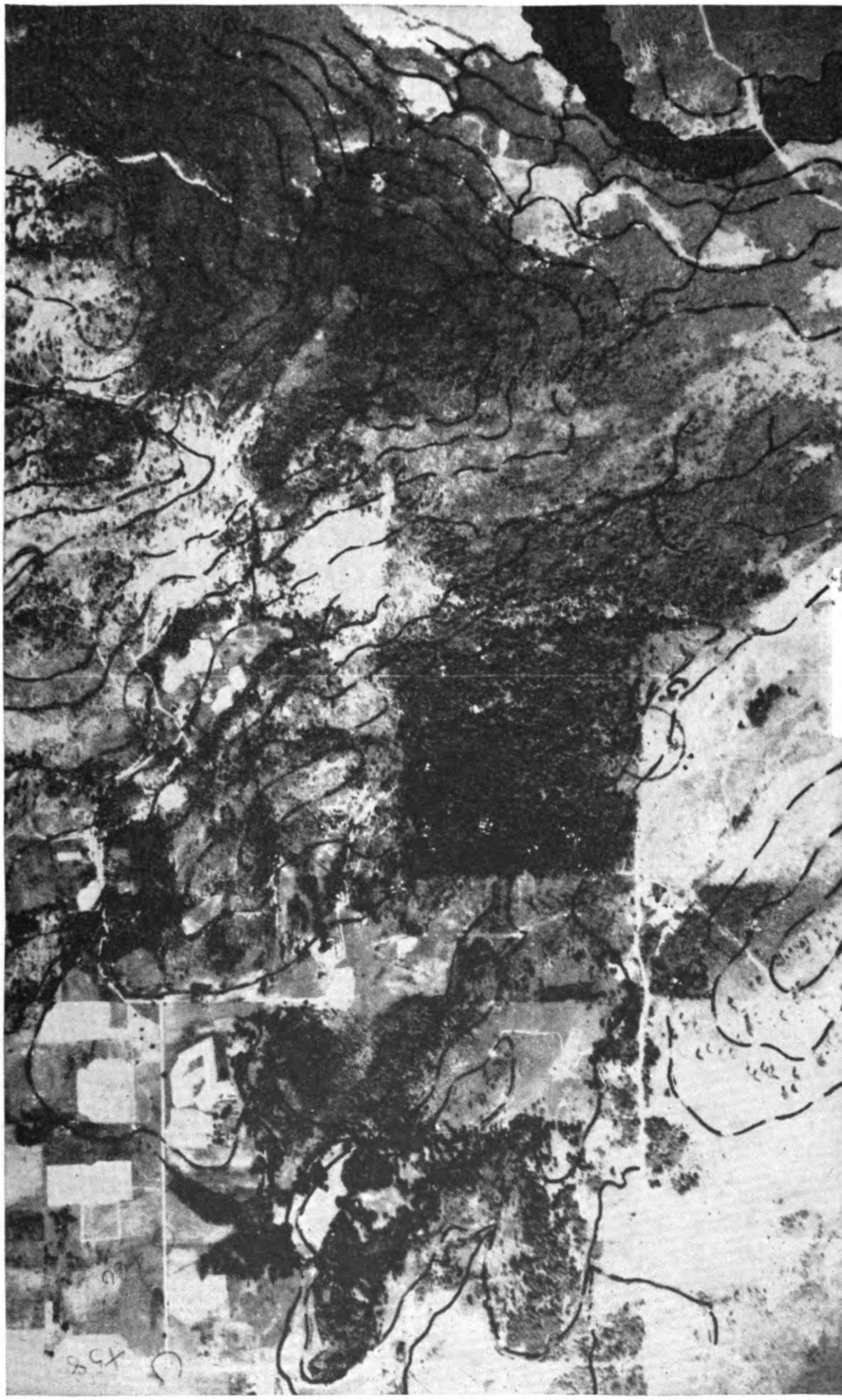
the same time to secure as good a match of detail as is possible. The perfect matching of detail will not be possible, and in appearance

the controlled mosaic may not be as impressive as the uncontrolled mosaic. However, such a mosaic, while not eliminating normal photographic displacements, does prevent the accumulation of these displacements and can therefore be scaled for long distances with much better results. (See fig. 47.) Controlled mosaics are difficult to prepare properly. If, aside from the inherent photographic displacements, a controlled mosaic of map accuracy is desired, it must be recognized that almost as much time and work are required as for a topographic map.

68. Contoured photomaps.—Any photomap consisting of individual photographs or portions of mosaics prepared as described above may be contoured by means of the stereocomparagraph, if stereoscopic coverage and vertical control are available. Each stereoscopic pair may be set up under the stereocomparagraph and a duplicate copy of the left photograph used as a templet on which to plot the contours. This will provide contours for one half the photograph, and the other half can be accomplished by setting up the proper stereoscopic pair under the instrument, using always the same photograph under the left floating mark. If vertical control is not available, the task of preparing contoured photomaps corresponds in difficulty with the task of producing topographic maps, and should not be attempted. If form lines alone will suffice, these may be added to a photomap by means of the stereocomparagraph or the stereoscope. (See fig. 48.)

69. Provisional maps.—A provisional map is a map substitute consisting of a planimetric extract of valuable information from an aerial photograph or mosaic of an area. On occasions when the nature of the terrain is such as to result in photography difficult to read or use as a map substitute, and most particularly during night operations, it may be desirable to extract the essential information from the photographs and to reproduce this information in the form of a provisional map substitute. (See fig. 49.) Form lines may be added, if desired, but only at a considerable cost in time. These provisional map substitutes contain all of the displacements common to the photography and are therefore no more accurate than the photographs themselves. Errors in interpretation of photographic detail may cause such a substitute to be less accurate than the photographs themselves, although the chances are that experienced operators will produce a result more acceptable to the average user than the photographs would be. In the preparation of provisional map substitutes, a sheet of transparent medium such as cellulose acetate is placed over the photograph and the plani-

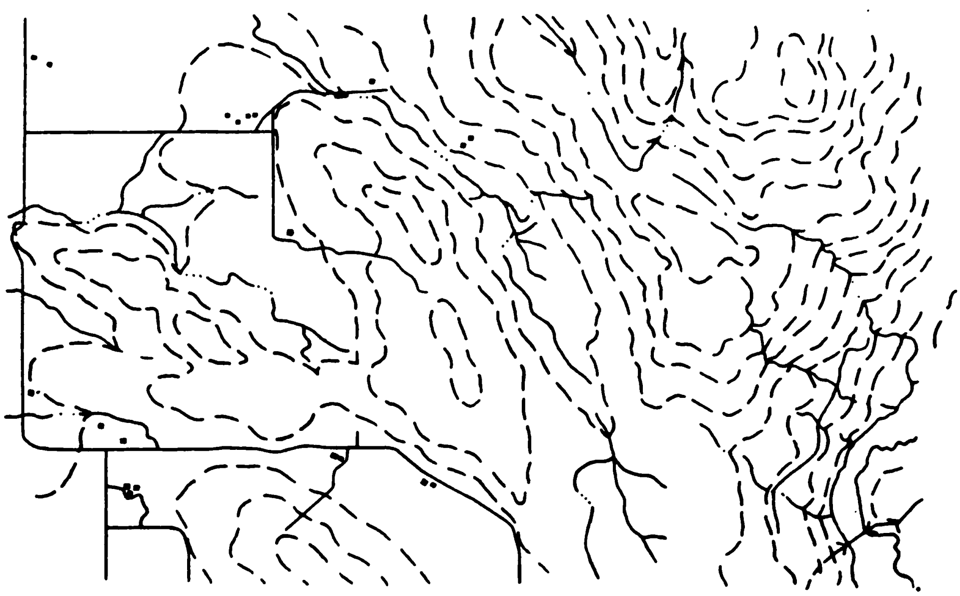
FIGURE 48.—Portion of contoured mosaic.



① Photograph with form lines.

FIGURE 49.

metric detail desired is extracted to this medium by direct tracing. The photographs must be studied stereoscopically to aid in the interpretation of detail, and all useful planimetry should be taken off. The conventional signs should be used for culture and hydrography, but a float symbol (a printed symbol on a transparency which may be pasted on and trimmed to proper shape) may be used to good advantage to represent woods. Form lines to represent only the general conformation of the terrain may be added if deemed desirable and time permits. An atlas grid and such names as are available should be added. If conditions warrant it, a combination of line map substitutes and the original photographs both may be supplied to the field forces, and this combination may serve the purpose of a map substitute admirably until the topographic map is available.



③ Line map with form lines.

FIGURE 49—Continued.

Appendix I

TRAINING NOTES

1. The training of a photomapping company requires the greatest length of time, and plans must be prepared to receive, process, and develop new men promptly to take their positions in the organization. It is desirable to start with men of at least high school education and having very good vision. The occupational specialists who will most readily develop in training are men who have had experience in photomapping in civil organizations, civil engineers, topographic surveyors, and draftsmen.

2. The procurement of occupational specialists fitted by prior experience for training in photomapping may be considered as exceptional under normal circumstances, and the normal type of replacement considered to be a high school graduate of no specialized training whatsoever. The training program should be based on this type of individual who must be taught everything a man must know with respect to his assignment. For many of the assignments the field of specialized knowledge is broad. To attain as quickly as possible a state of training wherein maximum production is possible, the idea of teaching each man only one phase of the subject with a view toward the adoption of mass production methods has some appeal. Unfortunately, it is not possible, without testing, to determine which men of a group are adaptable to work with stereoscopic plotting instruments. It is also unfortunate that compilers or draftsmen must know a great deal about topographic drafting, the methods used in photomapping, and have the ability to study photographs stereoscopically before they may be expected to do their jobs well. Some of the more mechanical steps may be taught to the less receptive men who may then form a useful group in the production scheme. It may, however, be considered a rarity to realize a situation wherein production on a fixed schedule for each phase is realized. More often than not the demand for maps will be sporadic and subject to interruptions resulting from changes in priority. The method to be used in the photomapping stage may not be determined until the job has been presented, and this alone will call for maximum flexibility within the organization so that its capabilities may be utilized to best advantage. For example, although one man may mount composites fast enough to keep ahead of the normal production schedule, when a new job having greater priority is presented, it will be necessary, if composites

are used, to mount these composites with a crew of from 20 to 30 men. For a particular job, large working crews undertake each phase and progress with the map until the maximum plotting rate is attained. For plotting it is desirable to have at least as many photographers as there is equipment available. A mass production schedule can be started after the maximum plotting rate has been attained on priority missions, but even this schedule must be flexible enough to take care of differences in extent of areas to be covered in amount of field control available, in the nature of the topography involved, in the amount of culture involved, in the photography, etc. There will never be enough similarity between different jobs to permit the establishment of an ideal mass production system, but advantage must be taken of such mass production methods as may be adapted to the work in hand.

3. For the reasons outlined above it is desirable to conduct a general course of training for all men joining a photomapping company. This should be designed to familiarize each man with the organization and with map making, and to develop his special capabilities as quickly as possible. Recruit training may be combined with a little field surveying and plane-table topographic mapping to develop an understanding of mapping and to attain this end in an interesting way. Some indoor technical training may likewise be combined with basic training to good advantage.

4. When there is an opportunity to draw men from a replacement pool, it is desirable to pass as many as possible through a brief test in stereoscopy so that a selection may be made from among men who are not hopelessly inept or physically unqualified for such work. It is desirable to have as many men as possible in the organization who are potential phototopographers. The brief test may be accomplished in a few hours, if necessary, and should consist of an explanation of stereoscopy, the study of anaglyphs, viewing photographs stereoscopically with instruments, and a final test on a stereocomparagraph to determine whether or not the individual can in fact see stereoscopically and with what degree of acuity.

5. The training of phototopographers must be stressed, since many months of diligent application are necessary, and the rate of production of new mapping will be to a large extent dependent on these specialists. A normal photomapping unit will have enough equipment to put over 80 phototopographers to work at the same time when the topographic plotting stage has been reached. Working in three shifts, therefore, as many as 240 phototopographers could be used. To accommodate this number, two men occupy each multiplex table, and

one man is assigned to each stereocomparagraph. The planned strength of a photomapping company will not permit the training of the number of phototopographers mentioned above, but at least half that number should be trained. Following basic military and basic technical training, potential phototopographers may be developed with the stereocomparagraph or the multiplex equipment. With the stereocomparagraph a student may be permitted to accomplish every step, first under the supervision and later without aid. He should develop his own tip and tilt graph and practice plotting topography until the established standard of acuity in his perception has been attained. Particular care must be taken to insure that the student does not strain too hard to develop proficiency too quickly, but that he be required to hold the floating mark habitually off the ground initially and develop acuity gradually. A common fault found is the habit of dropping the floating mark below the point where depth perception disappears in an effort to force readings beyond the student's capacity. This habit will materially retard progress. Every student should be made thoroughly familiar with the need for the tip and tilt graph, and should be taught how to simplify it by swinging the photographs when necessary. The drafting of students should be of high quality to develop training in this field at the same time. When the multiplex equipment is used in the initial training of phototopographers, it has been found desirable to give a brief course in the operation and nomenclature of the equipment and to follow this with practice in topographic plotting on models set up by experts. Topographic plotting on perfect models is an interesting way to develop acuity of stereoscopic vision and a good way to teach men how things are supposed to look in a model free of parallax. When a satisfactory state of training is attained and the work of a student is acceptable for incorporation in a map, the student may then be permitted to make his own orientation, practicing first with training diapositives having thereon ruled lines only to get a good idea as to the effect of the various movements of the projectors. An expert multiplex phototopographer may be permitted to advance to control extension work when qualified to do so. As large a number of men as possible, talented in control extension work, should be developed, and this will require from 6 to 8 months of intensive training.

6. Draftsmen should have a thorough course in stereoscopy, radial line plotting, topographic drafting, and a limited course with the stereocomparagraph. They should know how to study photos stereoscopically, how to intensify them under a stereoscope, how to determine the true geographic location of any picture point, how to compile

detail from photographs to true positions, and how to compile stereocomparagraph topography. The compilation of topography especially requires special training and a thorough knowledge of the stereocomparagraph product.

7. Phototopographers and draftsmen are the backbone of a photomapping unit, and the greater the number available, the more flexible and capable the organization will be. Computers, editors, photo mounters, point prickers, slotted templet operators, projection plotters, photographers, etc., are specialists relatively few in number, and their training is either a simple routine or a matter of practice and experience. Men who fail to develop satisfactory acuity of vision for plotting machines may be trained in other specialties. It is highly desirable to have a minimum of men unsuited for stereoscopic plotting instruments, and to this end an effort should be made to predetermine this deficiency, if possible, or to arrange for replacements by transfers from other units after the deficiency has been detected both for the benefit of the individual replaced and the organization.

8. Some special training is required for photo laboratory personnel, largely for the purpose of developing skill in precision measurements.

9. Present developments indicate possibilities in the improvement or design of equipment which may make possible the plotting of any multiplex spatial model without the necessity of making control extensions in some cases where great accuracy may be sacrificed in favor of speed. Such developments may also make possible the rapid rectification of photographs by eliminating excessive tip and tilt to the point where no tip and tilt graph will be required in stereocomparagraph plotting. The possibility of plotting any multiplex spatial model for which there are no known elevations is worthy of continued research by all photomapping establishments, and is a problem to test the mettle of the most advanced operators. For experimentation along this line, a data recording unit giving precise information as to the flight height, instruments precise enough to measure projector heights to within 0.1 mm, determination of the projection characteristics of each projector to within 0.1 mm in bz, a precise radial line plot to establish scale in each model, and pending the development of instruments to record the tip and tilt of the camera, an ability to horizontalize a model by reference to topographic or planimetric features are all necessary to a fair result. Although not as yet perfected, the possibilities along this line should be borne in mind.

10. The noncommissioned officer staff of the photomapping company of at least the first three grades should be thoroughly schooled in all phases of photomapping.

11. A substantial group of men of the photomapping company should be thoroughly trained in laying controlled and uncontrolled mosaics, and in making all forms of map substitutes.

12. In the photomapping company no opportunity to utilize the maps of other agencies should be overlooked. The compilation of a map from the work of other agencies may be the most important task for the photomapping company under certain circumstances. Also the revision of available maps where planimetry alone may be altered to conform to recent aerial photographs and thus provide a suitable map may be practiced by draftsmen to good advantage.

13. The field survey units, in addition to developing well-trained survey parties for second order triangulation, traverse and level lines, all well versed in the selection, pricking, and transmittal of picture points, should train at least two plane-table parties so that they may have available topographers to handle any small job of that nature which may be called for, and for which aerial photomapping is unsuited or impossible. Since normal missions do not require the use of plane tables or the training of topographers, the specialists involved must be developed through nonproductive training.

Appendix II

LIST OF REFERENCES

1. **Army Regulations.**
   AR 300-15, Maps and Mapping.
2. **Field Manuals.**
   FM 1-35, Aerial Photography.
   FM 21-25, Elementary Map and Aerial Photograph Reading.
   FM 21-26, Advanced Map and Aerial Photograph Reading.
   FM 21-30, Conventional Signs, Military Symbols, and Abbreviations.
   FM 30-20, Military Maps.
   FM 30-21, Role of Aerial Photography.
3. **Technical Manuals.**
   TM 1-220, Aerial Photography.
   TM 1-221, Tables of Coverage and Tables for Construction of Polyconic Projections for Aerial Photography.
   TM 5-230, Topographic Drafting.
   TM 5-235, Surveying.
   TM 5-236, Surveying Tables.
   TM 5-245, Map Reproduction in the Field.
4. **Miscellaneous.**
   Bulletin 650, United States Coast and Geodetic Survey, Geographic Tables and Formulas.
   Bulletin 788, United States Coast and Geodetic Survey, Topographical Instructions.
   Serial 592, United States Coast and Geodetic Survey, Magnetic Declination.
   S. P. No. 5, United States Coast and Geodetic Survey, Tables for Polyconic Projections.
   S. P. No. 26, United States Coast and Geodetic Survey, Field Work.
   S. P. No. 59, United States Coast and Geodetic Survey, Military Grid System.
   S. P. No. 120, United States Coast and Geodetic Survey, First Order Triangulation.
   S. P. No. 138, United States Coast and Geodetic Survey, Triangulation Computation and Adjustment.
   S. P. No. 140, United States Coast and Geodetic Survey, Leveling.

S. P. No. 145, United States Coast and Geodetic Survey, Second and Third Order Triangulation.

Multiplex Operators Manual by Engineer Detachment, Wright Field, Dayton, Ohio.

INDEX

INDEX

[A. G. 062.11 (6-24-41).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

DISTRIBUTION:

D1, 2, 7, 17(5); R1(5); I Bn 1, 5(10); IC 5(20).
(For explanation of symbols see FM 21-6.)

U. S. GOVERNMENT PRINTING OFFICE: 1941

For sale by the Superintendent of Documents, Washington, D. C.